PRACTICAL

DECEMBER 1987 · £1.25

ELECTRONICS

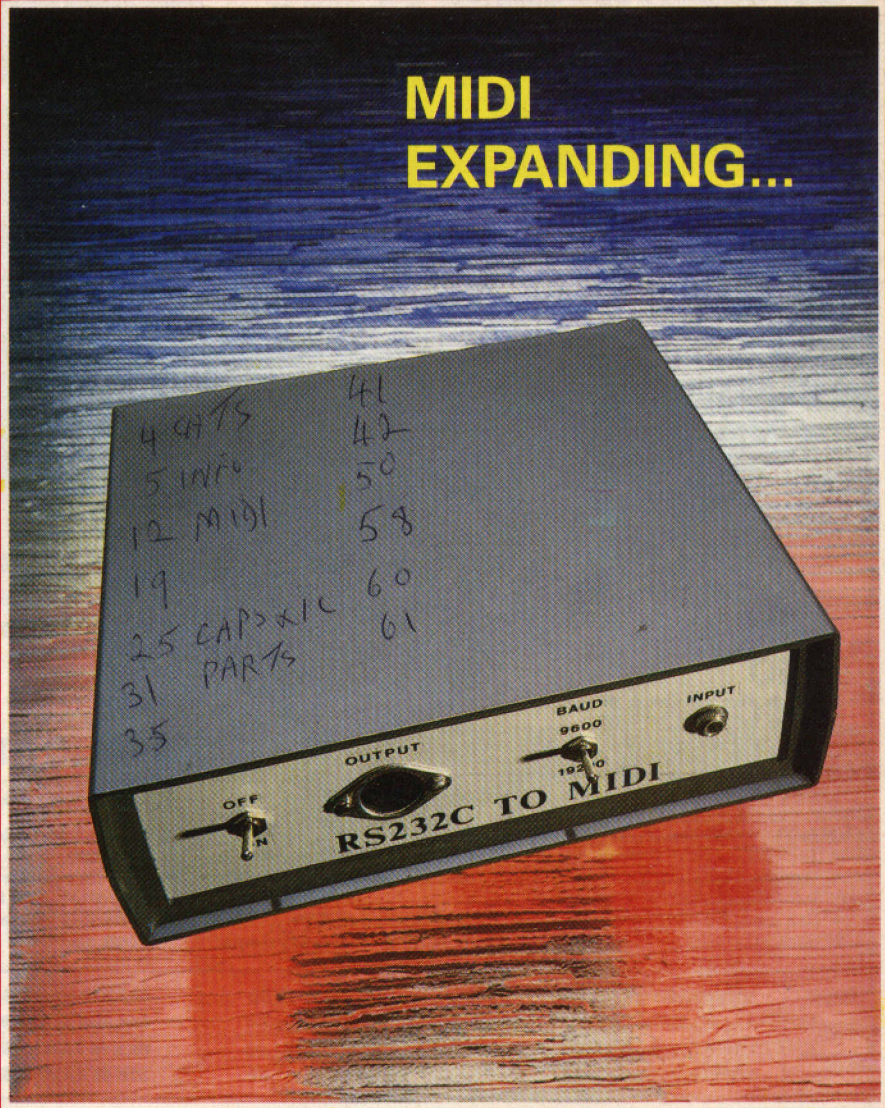
SCIENCE & TECHNOLOGY

BURGLAR ALARM

TEACHER RADIO

SOLAR CELLS

ANNUAL INDEX



DESIGN
SEMICONDUCTOR PRINCIPLES

COMPUTING
RS232C TO MIDI CONVERTER

TECHNOLOGY
TELEPHONE DEVELOPMENT

EXPERIMENTAL
AND PRACTICAL APPLICATIONS

PLUS:

- ★ SPACEWATCH
- ★ LEADING EDGE
- ★ INDUSTRY NEWS
- ★ LOGIC PUZZLE
- ★ MARKET PLACE

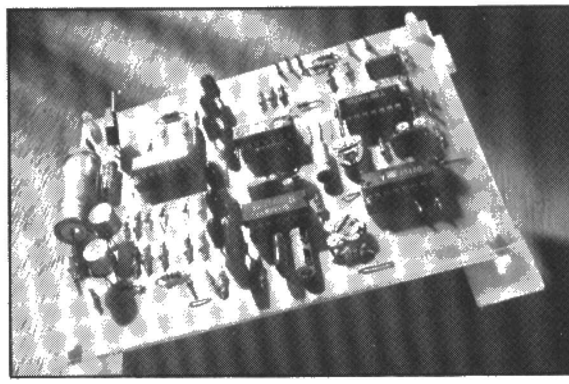
G.C.S.E. PROJECT IDEAS SERIES

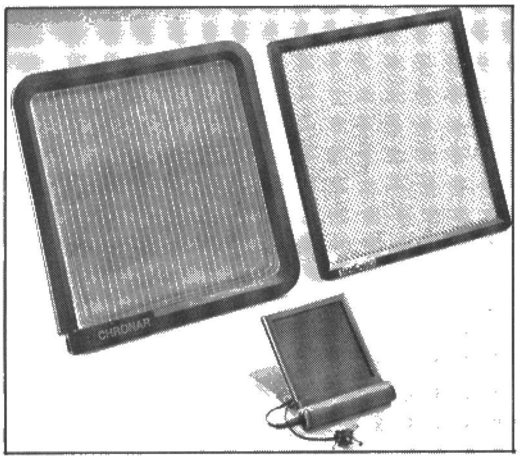
THE SCIENCE MAGAZINE FOR SERIOUS ELECTRONICS AND COMPUTER ENTHUSIASTS

PRACTICAL ELECTRONICS

PE VOL 23 NO 12 DECEMBER 1987

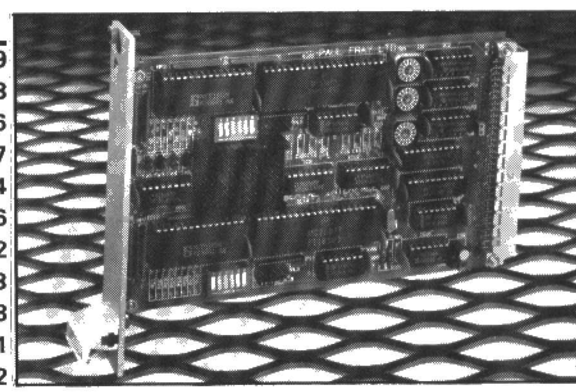
CONSTRUCTIONAL PROJECTS

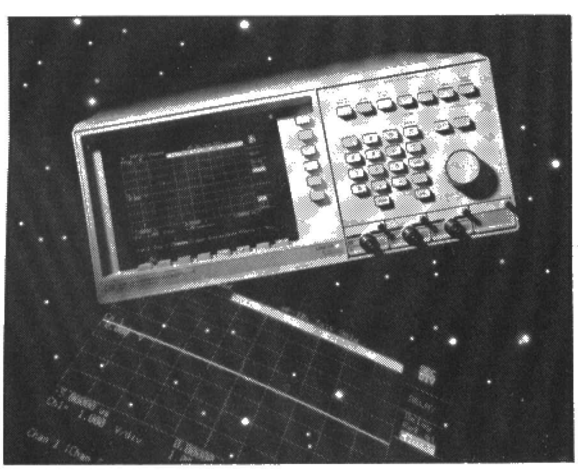




SPECIAL FEATURES

REGULAR FEATURES





NEXT MONTH . . .

The Yule-Tide issue has a veritable feast of features –
SANTALITE CONTROLLER • EGG LED TIMER • KIND MOUSE TRAP • LEGGO BUGGY DRIVER • INGENUITY UNLIMITED BUMPER BUNDLE • LCD COLOUR TV • TEACHER TALKBACK • HEAT SINKS • CODED LOCKS (sorry space didn't allow it this month) • **SEMICONDUCTORS •TELEPHONE HISTORY •**
AND of course we'll have our regular top line features and latest product information as well.

IN IT'S SPECIAL SEASONAL COVER THE JANUARY 1988 ISSUE WILL BE HARD TO KEEP YOUR CLAUS OFF!
ON SALE FROM FRIDAY DECEMBER 4TH
DON'T MISS IT
IT'S A GIFT AT £1.25

THE SCIENCE MAGAZINE FOR SERIOUS ELECTRONICS ENTHUSIASTS

CATALOGUE CASEBOOK

We have recently received the following catalogues and literature:

British Amateur Electronics Club. Once again they have produced another Newsletter, **full of interesting** information and letters. The Hon. Sec., **B.A.E.C.,** 53 High Oaks Close, Locks Heath, Southampton, SO3 6SX.

Electronic Organ Magazine. This has been a regular publication for many years, and is a **well produced and informative** journal. The Hon. Sec., **E.O.C.S.,** The Mill House, Mill Lane, Wheaton Aston, Stafford, ST19 9NL.

Why not think of joining B.A.E.C., or the E.O.C.S., or both!

Electronic Brokers' brochure and price list of **test equipment product ranges,** for which they state that they are the number one distributor in the UK. **Electronic Brokers Ltd.** 104-106 Camden Street, London NW1 9PB. 01-267 7363.

Hobby Drill 2000 catalogue detailing a collection of small tools, mostly based around a compact low voltage **miniature drill system,** for the hobby enthusiast or electronics professional. **JASP International,** 14 Tudor Close, Wokingham, Berks, RG11 2LU. 0734 782084.

Audiokits have released their latest catalogue of precision components and **high quality audio amplifier kits,** which naturally include the PE 30+30 amplifier (PE Feb-Mar 87), **Audiokits,** 6 Mill Close, Borrowash, Derby, DE7 3GU.

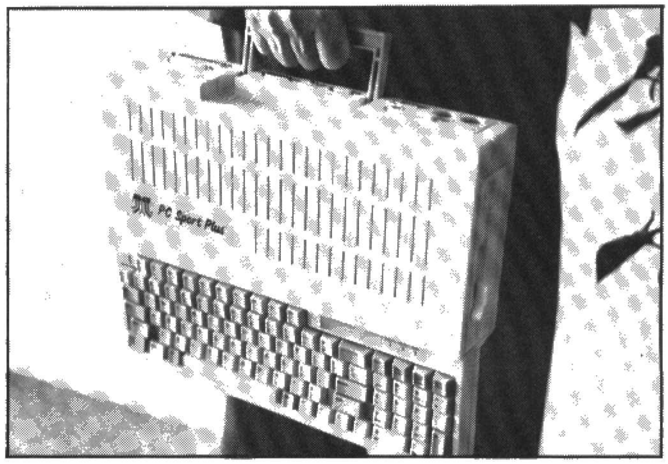
Phonosonics' latest short-form catalogue has been received, detailing kits for **many projects published in PE,** including the **Burglar Alarm** in this issue. **Phonosonics,** Dept 12ED, 8 Finucane Drive, Orpington, Kent, BR5 4ED.

The British Audio Dealers Association have published a 30 page glossy colour book on **choosing hi-fi,** and it's **FREE** to PE readers. **BADA,** The Sound Advice Centre, 40-41 Great Castle Street, London W1N 7AF.

Livingstone Hire have sent a promotional leaflet publicising the **electronic equipment that can be hired** from them. They claim to be Europe's 'No 1' company offering this service. **Livingstone Hire Ltd,** 2-6 Queens Road, Teddington, Middx. TW11 0LB. 01-977 8866.

Five Star Connectors offer 'the best choice ever for connectors'. Their **new 200+ page catalogue** adds considerable weight to their claim. **Five Star Connectors,** Edinburgh Way, Harlow, Essex, CM20 2DF. 0279 442851.

WHAT'S NEW



Sporty Piece

An innovative new portable is the latest addition to the growing range of IBM compatibles from AMT.

Powerful memory features are built into the PC Sport Plus. The conventional memory of 256K can be increased to 640K, and an additional 512K of expanded memory can be added on a separate memory bank giving extra room for packages such as Lotus 1-2-3 and Framework that support the EMS standard. Performance is bettered by few PCs, and PC Sport Plus runs at a turbo speed of 8MHz.

Those fortunate enough to lay their hands on the keys will find a standard layout with the addition of separate cursor keys, assisting numeric input to spreadsheets. Leds, ten function keys and a reset button are present too.

An integral 360K disk drive is built into the right hand side of the computer and an external drive can be connected at the rear. Communications are available with two serial RS232 ports, 25 pin and 9 PIN, a useful facility on a portable, allowing use of various modems without a converter lead. The display card is CGA (640 x 200) and allows use of both composite video monitors and colour displays. An EGA card is optional and will be available soon.

An eight-bit expansion slot on the left hand side adds growth potential, and an optional 4-slot expansion box is on the way. One unusual feature is specialized circuitry which allows most copy protected software to be backed up. Other features include a battery backed real time clock, parallel port for printer and games port for joystick.

The PC Sport Plus is priced at £499 + VAT. With Dos 3.2, 640K RAM and a monochrome monitor the system costs £703 + VAT.

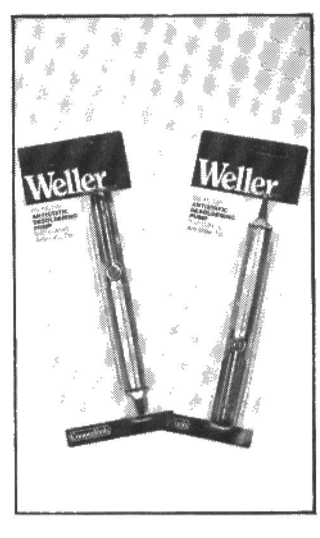
Contact: Applied Microsystems Technogy Ltd, 1st Floor, 249-251 Cricklewood Broadway, London NW2 6NX. Tel: 01-450 3222.

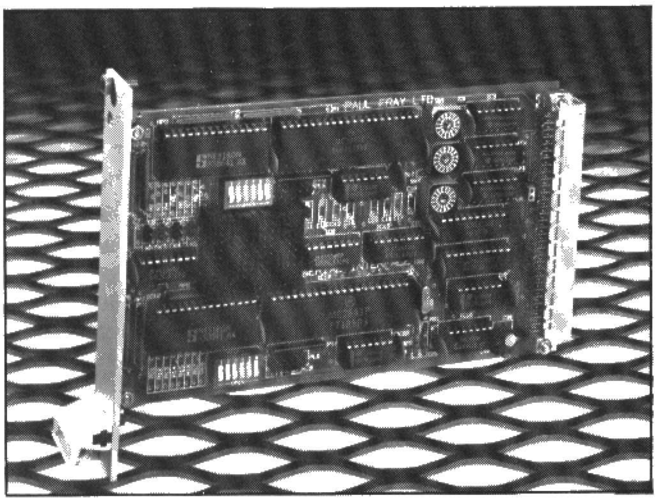
Pumping Lead

CooperTools have introduced two anti-static models to their Weller manual desoldering pump range.

Featuring fine 0.07in (1.9mm) diameter and general use 0.12in (3.2mm) diameter anti-static desoldering nozzles, the DS-AS-100 and DS-AS-110 allow one-handed operation, in conjunction with a soldering iron, to remove suction all the solder from around components requiring replacement on circuit boards.

For further information contact: Cooper Tools Limited, Sedling Road, Wear, Washington, Tyne & Wear NE38 9BZ. Tel: (091) 416 6062





Spider's Web

Paul Fray Limited, the Cambridge-based specialists in interfacing laboratory equipment to micros, has recently announced several new products to complement and extend its Spider 2 real-time package, and to allow its use with Acorn's new RISC machine.

A new version of the Cobweb 1MHz expansion card allows a micro (BBC models B, B+ and Master 128, Acorn Cambridge Workstation or Archimedes) to address up to 16 Mbytes on an industry-standard 'Cambridge Bus' backplane. This backplane can make use of a growing range of interface and memory cards.

A four channel serial interface card provides a large degree of flexibility: connectors and termination characteristics are available to customer order. Full modem support is implemented.

A 16 channel digital interface card allows 'bomb-proof' connection to laboratory experiments etc., at up to 30V d.c. Each opto-isolated channel may be an input or an output, selected under software control. Spider 2 is found in motor-car endurance testing, saw-mill management, robot supervision, wind-speed measurement, satellite telemetry, nutritional analysis, behavioural pharmacology and many other fields in schools, universities and industry.

Contact: Alasdair Hayden on Cambridge (0223) 66529.

COUNTDOWN

If you are organising any electronic, computing, electrical, scientific or radio event, big or small, drop us a line. We shall be glad to include it here.Send details to **COUNTDOWN**, Practical Electronics, 193 Uxbridge Road, London W12 9RA.

PLEASE NOTE: Some events listed here may be trade only, or restricted to certain categories of visitor. Also, please check dates, times and other relevant details with the organisers before setting out as we cannot guarantee information accuracy.

Regular courses for R.A.E., and also for Morse. Grafton Radio Society, Elizabeth Garrett Anderson School, Riseing Hill Street, London N1.

Regular weekly courses for Radio Amateurs Exam (C8G 765). Tuesdays 7.30 to 9.30. Hendon College, Corner Mead, Grahame Park, Colindale, London NW8 5RA. Tel: 0-200 8300.

Nov 3–Dec 10. Research and Development Society Silver Jubilee Exhibition. The Design Centre, London. 01-235-6111.

Nov 5–8. Reproduced Sound Conference — IOA. Windermere Hydro Hotel. 031-225-2143.

Nov 10–12. Drives, Motors, Controls and PC+ Systems '87. National Exhibition Centre, Birmingham. 0799-26699.

Nov 19–20. Desktop Publishing. Cumberland Hotel, London. 01-871 2546.

Dec 17–18. Underwater Communication Conference — IOA. University of East Anglia, Norwich. 0603 592582.

Jan 27–28. Instrumentation Coventry. Trade only. Allesley Hotel, Coventry. 0822 4671.

Feb 24–25. Instrumentation Bristol. Trade only. Bristol Crest Hotel, Bristol. 0822 4671.

Mar 29–30. Instrumentation Harrowgate. Trade only. Harrowgate Exhibition Centre, Harrowgate, N. Yorks. 0822 4671.

Ecology Conscious

A recent press release informed me that Vidor batteries are being used in a mole mover; I was intrigued enough to follow up the story.

It turns out that PAL Electronic Systems are the company with the kind hearted design team. Being conscious that wild life has its essential place in nature, they believe that unwanted intrusion by animals is better cured by deterrence rather than destruction. Their environmentally safe electronic device to combat mole infestation puts their hertz where their hearts are.

Known as the Kestrel Molemover, the battery powered device has a probe that is inserted into the soil close to known mole runs. It generates a modulated sound disturbance which makes use of the moles' high sensitivity to sound vibration to encourage them to stay away.

Depending on soil conditions, the Molemover will effectively stop mole damage over an area of 750 to 1100 square metres, and operates in temperatures ranging from −20°C to +40°C. Its compact design and light weight of only 1kg, including battery, makes it ideal for use in gardens, parks, golf courses, airfields and other areas where moles can cause problems (no mention of MI5 or MI6 though). The Vidor Powercell Long Life alkaline 1.5V batteries will operate the device constantly for approximately six weeks.

PAL are equally kind to birds and rodents. Their Rat Router uses advanced modulated ultrasonic techniques to evict rodents from reserved residences. Being electrically safe, non-toxic and non-lethal, it is environmentally safe and hygienic for use even in food containing areas.

Their Bird Blaster doesn't use shot guns, but instead emits blasts of sound and light to deter would-be crop raiders without actually scaring them. They also have a Bird Ejector that uses ultrasonics to overcome the problem of birds in and on buildings without killing them. Both units are portable and environmentally safe.

Using electronics in this fashion to guard the interests of both humans and wild life has my encouraging approval. I wonder if they will invent a unit to eliminate bugs from programs.

Contact: PAL Electronic Systems Ltd, PO Box 7, Oadby Industrial Estate, Leicester, LE2 4YE. Tel: 0533 713361.

Pirate Destruction

A Nigerian court has recently ordered the destruction of 200,000 pirate music cassettes containing works by over 300 classical, jazz and pop artists. This is the latest in a series of legal moves by the local music industry against importers and manufacturers of illicit tapes and follows a recent pledge by a senior government minister that measures to eradicate piracy will be introduced by the end of 1987.

The ministerial statement was made by the Attorney-General, Prince Bola Ajibola, during a top-level seminar organised in Lagos by the Nigerian IFPI group, representing recording companies, the Nigerian Television Authority and the country's musicians' union. Among the speakers were industry officials and leading Nigerian lawyers. In his speech, Prince Ajibola acknowledged that the country's 1970 Copyright Act was obsolete and added that revised and "stiffer" copyright legislation was in the offering.

Nigeria is the largest market for recorded music in Africa, with annual sales of some 23 million records and cassettes. Of these, however, some 70% are pirated, with a retail value of 96 million naira ($30 million). Although hampered by the inadequate state of the current law, IFPI's Nigerian group has won four major anti-piracy actions in the Lagos courts in the last twelve months. The cases brought against manufacturers, imports and printers involved in piracy, resulted in the imposition of damages totalling over 120,000 naira.

Peter Crockford, IFPI's Anti-Piracy Co-ordinator, commented that "The Attorney General's statement is most encouraging since it is the first formal public commitment by the Nigerian government to the introduction of copyright reforms. IFPI has already submitted its proposals to make prosecutions easier and penalties heavier and we hope to see these included in the forthcoming legislation.

Contact: IFPI Secretariat, 54 Regent Street, London W1R 5PJ.

CHIP COUNT!

This month's list of new component details received — mainly chips, but other items may be included.

68C257 and 87C257. Specialised 256Kbit CHMOS Eproms for microcontroller-based systems. **(IT).**

83C152. CHMOS Universal Communications Controller incorporating the 8051 instruction set, and hard wired SDLC-HDLC and CSMA-CD communication protocols. **(IT).**

BD1. Intelligent alphanumeric display, combining a 16 character, 14 segment vacuum-flourescent display and on board controller **(HS).**

LM211XB. High performance LCD screen capable of displaying graphic or alphanumeric data, its 64 × 480 dot matrix format allows up to eight rows of 80 characters. **(HT).**

TM2. Transputer based module. High quality, 95 × 74mm, four layer PCB on which are mounted a T414-15 transputer (capable of 7.5 million instructions per second) and 1Mbyte of DRAM. **(CT).**

TP4192. 500ns A-D converter with 12-bit resolution in three selectable input rages up to 20V. **(TP).**

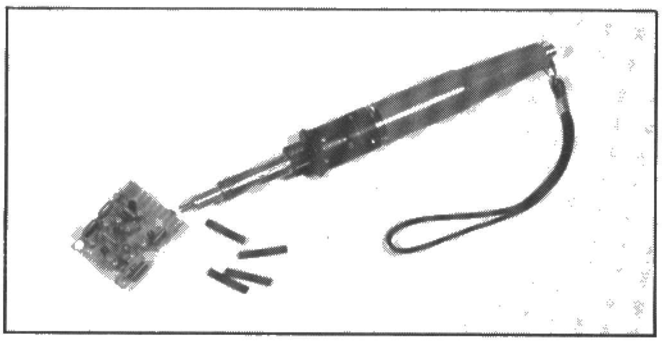
Manufacturers, and contact telephone numbers for further details. (CT) Concurrent Techniques, 0424 714790. (HS(High Speed Technology, 0602 587225. (HT) Hitachi, 0923 246488. (IT) Intel, 0793 696204. (MC) MCP Electronics, 01-902 6146.

Heatshrink

Master HeatTools announce the availability of a range of heatshrink attachments for their Ultratorch 3 in 1 heat tool. With an outside diameter ranging from 8.0mm down to a minute 2.5mm the tips are ideal for small or inaccessable heatshrinking and drying work.

The Ultratorch 3, as well as being a heatshrink tool, can also be used as a soldering iron and is powered by inexpensive butane gas making the unit completely portable.

Contact: Master Heat Tools, Unit M, Portway Industrial Estate, Andover SP10 3LU Hants. Tel: (0264) 51347/8



Bus Battery

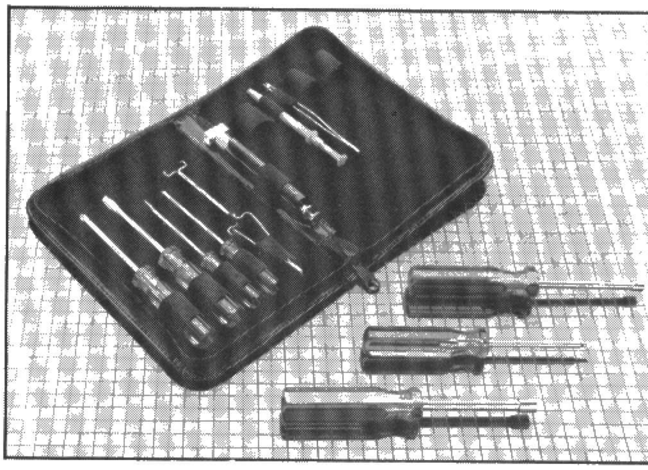
The SM256 is a bytewide memory card for the STE Bus from DSP Design. It has 8 sockets to take any mix of SRAM, EPROM or EEPROM up to maximum of 256 Kbytes. 8 Kbyte, 16 Kbyte or 32 Kbyte chips may be used.

Battery backup is provided on the board, and the user can select which sockets to support. The battery is switched in either when the main 5V supply drops too low or when the STE Bus SYSRST signal is asserted.

Flexible memory addressing allows the card to be mapped anywhere in the 1Mbyte STE Bus address space and to occupy from 64K up to 256K, depending on the memory chips used. Individual sockets can be made to 'disappear' from the memory map to avoid clashes with other memory devices.

Jumpers allow the user to select the access time of the board, for optimum system performance, from 50 to 250nS in 50nS steps.

The SM256 is available at £139.50 one-off. All enquiries to: **DSP Design Limited, 100 St Pancras Way, London NW1 9ES. Tel: 01-482 1773**



Chip Kit

A new electronic servicing kit that includes a range of integrated-circuit handling tools as well as screwdrivers and nutdrivers has been introduced by Global Specialists.

The CSK-8 kit contains an i.c. insertion tool with pin straighteners for 14 and 16 pin devices; an extraction tool with pin straightener for 14 to 40 pin devices; a three-claw parts holder; assembly tweezers; a selection of slotted and Phillips screwdrivers; two nutdrivers; and a torque screwdriver.

The kit is supplied in a zipped vinyl case measuring 23 x 15 x 14 cms and costs £22.50.

Contact: Global Specialists, Shire Hill Industrial Estate, Saffron Walden, Essex, CB11 3AQ. Tel: 0799 21682.

Trading Pops

Pops Electronic Components is a new Company that has been formed to cater for the electrical, electronic and wholesale, trade, specialising in potentiometers, switches, plugs, sockets, leads, fuses, test meters etc.

Pops has been established by Clive Coleman and Peter "Fred" Gosling who between them have over 50 years experience in the wholesale and retail trade. They were formerly with the K. Popper (R.T.C.) Ltd Organisation, have now set up their own business at Staples Corner, London.

Clive and Fred will be happy to deal with all enquiries from trade customers both old and new, UK and abroad. Small and large manufacturers, technical colleges, universities and schools are also welcome.

For further information contact: Pops Electronic Components Ltd, Studio D, Unit 9A, Oxgate Lane, London, NW2 7HU. Tel No.: 01 450 4688/9 (24 hour answer phone).

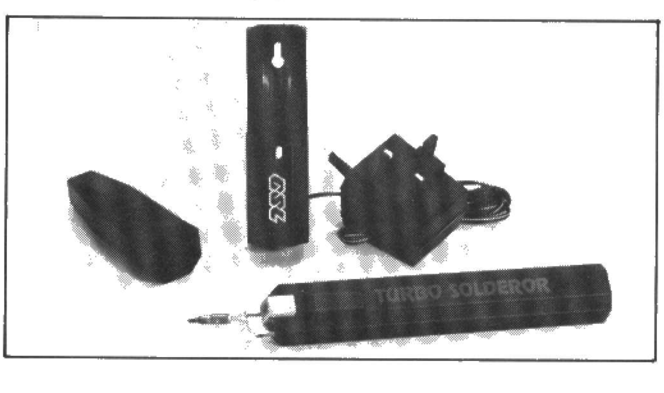
Tip Charge

Cirkit has introduced a new rechargeable soldering iron, which is ideal for soldering CMOS and other static sensitive devices and for site work where no mains supply is available.

Rated at 12W with fast warm-up time and small 2mm diameter tip, the unit comes complete with mains charger, wall mounted socket and a 12V car charging lead which is connected via a vehicle's cigarette lighter. Up to 200 standard joints can be made from one charge of 12 hours.

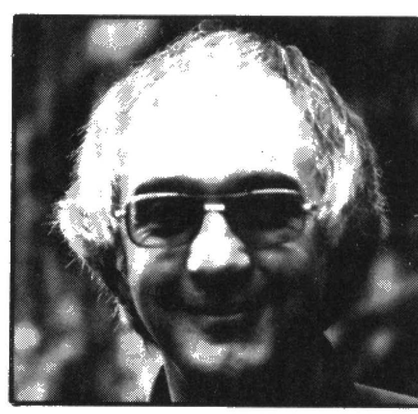
Featuring an illuminated tip, for which spares are readily available, the soldering iron also has a safety hood for protection during operation.

Contact: Cirkit Holdings PLC Park Lane, Broxbourne, Hertfordshire EN10 7NQ. Tel: (0992) 444111



THE LEADING EDGE

BY BARRY FOX



RED FACES AT PHILIPS

Advances in digital recording techniques and television picture processing, and the offer of a constructive solution to the "Copycode" debate is received with horror.

Rock guitarist and composer Pete Townshend of The Who has his own recording studio by the edge of the River Thames near Richmond lock and is using computer disks instead of magnetic tape to record his new album. The recorder, which costs around £100,000, also controls a bank of video recorders so that Townshend can mix and match film sequences in synchronism with the music.

The system is the Synclavier direct-to-disk multitrack recording system, made by New England Digital of Vermont. Instead of using reels of magnetic tape, it converts analogue sound into digital code and stores it on four Winchester hard disks, like computer data. Each disk hold 150 megabytes of data, so the system has a total capacity of 4.8 gigabits. This is partitioned into eight parallel streams to create the equivalent of an 8-track digital track recorder. For studio quality recording the sound signal is sampled at 50kHz and coded into 16 bit words. Each of the eight tracks can then store 13 minutes of music.

The big advantage of the system is that there is virtually instant access to any part of the recording, without time wasted on rewinding tape. Pete Townshend is now using the system to help him write music for films. The magnetic disks are electronically locked to four video tape recorders. Any or all of these contain a sequence of film for which music is to be written, together with shots of Townshend conducting an imaginary orchestra. When the magnetic disks and video recorders are run together, all the musicians making the recording can watch the film sequences and the conductor on a bank of monitor TV screens. The pictures and sound remain in perfect synchronism however many attempts are made at making the recording.

As computer users will well know, Winchester hard disks are never 100% reliable and may "crash" losing all the data. No musician wants to risk losing months of work so the Synclavier incorporates four tape "streamer" cartridges, made by Fujitsu of Japan. At the end of each recording session the four cartridges are run in parallel to make a safety back-up of the digital data on the disks. It takes less than five minutes to make a bit-perfect back-up of a three minute 8-track sound recording. If the hard disks subsequently crash, the data can be reloaded from the tapes without any loss.

The next generation of domestic video recorders, and TV sets, due to go on sale in Britain this winter will use digital computer techniques to give clearer pictures from poor aerials and old video tapes. The technique is called 'picture noise reduction', and Japanese shops are already selling sets which make TV pictures look much cleaner and crisper than ever before.

Video noise is always a problem with TV and video. Flecks of white, like snow, or spurious colour spots, like confetti, blemish the picture when the signals coming down from an aerial, or off a video tape, are too weak. Video noise reduction gets rid of the snow and flecks by taking advantage of two electronic phenomena.

When a TV set displays 50 half picture 'fields' a second most of the information in one picture is very similar to the information in the next, because most TV scenes are static views except for a little localized motion. But noise is random. The snow pattern which blemishes one TV picture is completely different from the snow pattern which blemishes the next.

If two TV pictures are added together the useful and wanted picture information is doubled, but the unwanted noise is increased only by a factor of 1.414 ($\sqrt{2}$). So unwanted noise is reduced by around 30% ($2 - 1.414/2$).

So far only professional equipment has taken advantage of this technique, because the solid state memory needed to store the TV pictures for summing is very expensive. Now the cost of solid state random access memory chips is low enough for domestic manufacturers to build picture noise reduction circuits into domestic video recorders and TV sets.

The incoming analogue TV pictures are converted into 6-bit digital code, stored in RAM, summed to reduce noise and then converted back into analogue signals for display on a TV screen in the usual way.

Japanese company NEC has further improved the system with what it calls "noise wiper" circuitry. Instead of just summing consecutive pictures to reduce noise, the noise wiper sums each new picture with the previous noise-reduced picture, which was itself the sum of two previous pictures.

DAT SAGA AGAIN

In an extraordinary new twist in the saga of DAT technology and politics a lawyer from Philips of the Netherlands says his company has come up with an ingenious idea for stopping people copying from disc records onto digital audio tape. But this is acutely embarrassing to Philips because it upsets plans by Philips's own subsidiary Polygram to use the much criticised Copycode system.

Copycode, developed by CBS, would suck an identifying notch out of the sound of every record sold to the public. When a tape recorder, compelled by law to incorporate a notch-sensing circuit, is asked to tape a Copycoded record, it simply switches off. Since May 1986 the record companies' world trade body, the IFPI, has been lobbying the Common Market law makers in Brussels and American government to pass the necessary laws.

Doubtless fearing the rebellion against Copycode which is now reaching fever pitch in the audio industry, the IFPI and CBS waited a full year before it demonstrated Copycode to the audio press and recording engineers who would have to use it. And then the demonstrations were given only to a few of the people who worry about what Copycode to the audio press and recording engineers who would have to use it. And then the demonstrations were given only to a few of the people who worry about what Copycode will do to recorded music.

Although the system will dutifully switch off a recorder, it creates an effect on music which the President of the prestigious Audio Engineering Society has described as "castration". In

Continued on page 45

PE SCIENCE AND TECHNOLOGY

VOLUME 23 No. 12
DECEMBER 1987

ISSN 0032 – 6372

Editor:
John Becker
Sub-Editor:
Helen Armstrong
Technical Illustrator:
Derek Gooding
Advertisement Sales:
Ian Forbes, Mike Thorburn, Richard Murphy
Publisher's Assistant:
David Hewett
Publisher:
Angelo Zgorelec
Editorial and Advertising Address:
Practical Electronics,
Intra House, 193 Uxbridge Road,
London W12 9RA
Tel: 01-743 8888

Advertisements

All correspondence relating to advertisements, including classified ads, should be addressed to: **The advertisement department, Practical Electronics, at the above address. Tel: 01-434 0689**

PE Services

Practical Electronics offers a wide range of services to readers including: p.c.b.s, books, subscriptions, and back numbers. However, due to increased administration costs we can no longer provide photocopies of articles over three years old.

Readers' Enquiries

All editorial correspondence should be addressed to the editor and any letters requiring a reply should be accompanied by a stamped addressed envelope.
We regret that lengthy technical enquiries cannot be answered over the phone.

Subscription Address:

Practical Electronics, Subscription Dept., P.O. Box 500, Leicester LE99 0AA

Annual Subscription Rates:

U.K. £15.00 Overseas £18.00
Students: Deduct £1 and quote student number.

Cover Photo:

Chris Bell

TECHNOELOGY

Napoleon, I think it was, said that we are a nation of shopkeepers. I say we are just as much a nation of customers and customs. One custom has been that the December issue of a magazine should celebrate Christmas. Well, here we are, the December issue, but I'm not wishing you Merry Christmas now.

'And why not?', you might ask, counting the shopping days left. That's just it, there are too many days left, despite the cover date. PE is published on the first Friday of the month before the issue date. I suppose this helps to prove we are the magazine that presents future technology now. It's actually for reasons of distribution logistics, though it sometimes creates a feeling akin to deja-vu and jet-lag in the editorial office. This column for example, first hit the keyboard in July, just after you received the August issue!

I certainly don't want Christmas on November the 6th, but I am offering a compromise — an early warning present. Unless someone has St Nicked it, there is an extremely useful gift attached to the front cover that surpasses seasonal benefits. Full of rainbow hues, this irresistible chart of resistor and capacitor colour codes, plus symbols and circuits should be of long lasting value to any one who is becoming addicted to the fascination of electronics. For more experienced addicts a few formulae are also freely offered.

These won't answer imponderables like the current flat rate charge for an ohmless bus driving superconductor, or whether the cut off frequency of a circular SAW filter is subject to Planck's law. They will confirm though, the Ohm's law relationship between resistance, current and voltage, as well as provide equations for calculating capacitor values and time constants. The selection of op-amp circuits should also be highly useful information to experimenters; I've selected those that I believe will have widest appeal.

Anyone newly becoming intrigued by electronics should find that the hi-technocolour code charts are invaluable, easy to use, and easy to learn. An interesting point, though, is that although common resistors are usually coded, some other components that used to be coded are now having their identities printed on in alpha-numerics instead. I imagine that it's probably cheaper, and also that possibly it helps those who are colour blind. It is chastening to think that many are afflicted in that way, even amongst regular readers and project builders.

Electronics and other technologies have brought many benefits to medical science, in particular in the investigative and corrective fields, but so far as I know, science has not yet come to the aid of those who are colour blind. No doubt it will one day.

Meanwhile, we are trying to help other quests for knowledge through this pre-noel present of code crackers and symbolic feasts. I will save the greetings till next month; don't miss the Christmas issue, it's exceptionally interesting.

THE EDITOR

PLEASE NOTE OUR NEW ADDRESS

OUR JANUARY 1988 ISSUE WILL BE ON SALE FRIDAY, DECEMBER 4th 1987 (see page 2)

You've heard the one about the drummer, the guitarist and the synth programmer? Well, here's a MIDI interface that even a drummer should be able to operate...

RS232C TO MIDI CONVERTER

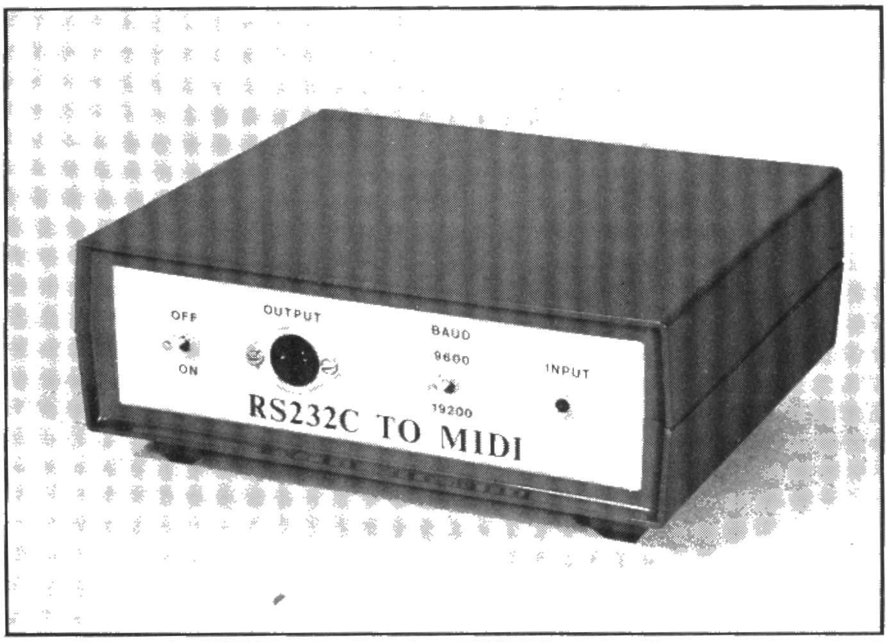
BY ROBERT PENFOLD

MINI MIDI

ALTHOUGH the MIDI (Musical Instrument Digital Interface) has gradually gained great popularity with manufacturers of electronic instruments, it has not had the same impact in the computer world. A few computers (such as the Atari ST series) have MIDI input and output sockets as standard, but in most cases control of MIDI equipment is only possible with the aid of some external hardware. For some computers there is no ready–made add–on MIDI interface available. If a really advanced computer controlled MIDI system is required there is probably little alternative to opting for commercial software, and to obtain a computer for which suitable software and hardware are available. Even if you have the ability to design the hardware and software, this is the type of thing where the amount of time involved is not so much a matter of man hours as man years!

If a more basic set up is all that is required, the do-it-yourself approach becomes a much more attractive proposition. Something like a simple step–time sequencer program is not too difficult to write, and software to produce a repetitive backing can be very simple indeed. One of the most useful applications of the MIDI system is to provide a programmable backing over which a "live" performance can be played. In many cases it is not even necessary to have separate instruments to provide the backing and the melody line, as most MIDI equipped keyboard instruments can be played simultaneously via the MIDI input and the keyboard.

There are various ways in which a MIDI output can be added to a computer, including a custom design to fit onto the buses of the machine concerned. The aim of the current design is to provide something more universal, and this really means an add–on to be driven from either an RS232C or Centronics port (these being the only common forms of standard interface). Both can provide signals that are readily



convertible to the MIDI standard, and the choice of an RS232C serial port as the signal source was mainly on the grounds that the most popular computer peripheral is a printer driven from the Centronics style parallel output port. With most systems the serial port is the interface which is most likely to be free for use with a MIDI converter.

EXCHANGE RATES

The unit will provide a MIDI standard output from any RS232C (or RS423) serial port that can provide an output at 9600 or 19200 baud with a word format of one start bit, eight data bits, one or two stop bits, and no parity. Every computer serial interface that I have encountered has been capable of supporting at least one of these options. The unit is essentially a baud rate converter, and as such it could have applications in other fields of computing, although it would require some modification in order to accommodate different baud rates and output signal standards.

A MIDI interface is a form of asynchronous serial interface, and as such it has more than a few similarities to the RS232C system. There are two areas of incompatibility between these two types of interface. The first one is the non–standard MIDI baud rate of 31.25 kilobaud, which compares with a maximum standard RS232C baud rate of 19.2 kilobaud. In fact the MIDI system did originally use a baud rate of 19.2 kilobaud, but before it was launched commercially an increase to 31.25 kilobaud was made. This gives better synchronisation between channels when all sixteen MIDI channels are in use. Some RS232C interfaces have the baud rate controlled by a crystal controlled clock oscillator and a divide by 'N' circuit, and an output at the correct baud rate for MIDI use might then be possible. This is something that is applicable to very few computers though, and in the vast majority of cases some extra hardware is needed in order to provide the boost in baud rate.

For those who are unfamiliar with the nature of serial signals, the waveform diagram of Fig.1 should help to clarify the way in which the unit functions. The word format used for the MIDI system is one start bit, eight data bits, one stop

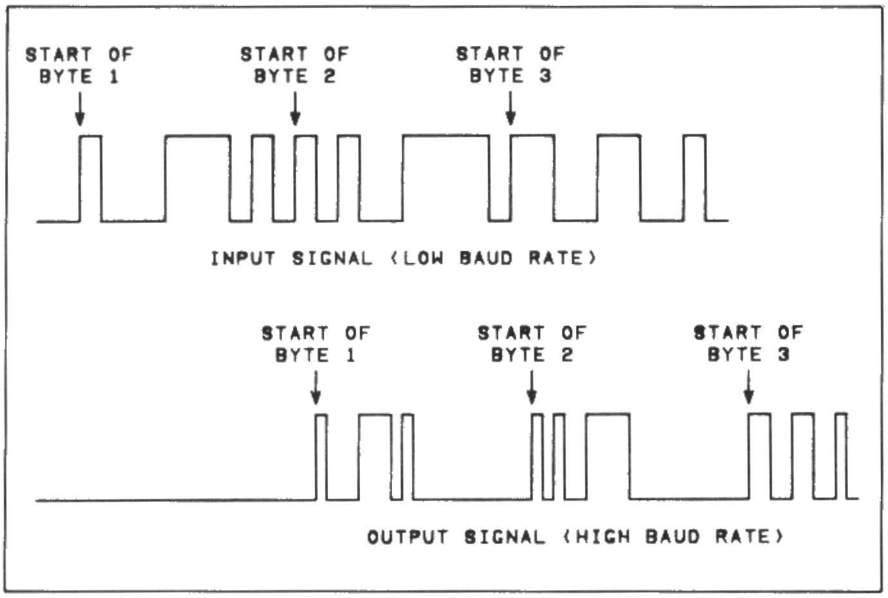


Fig. 1. *Input and Output wave forms for a baud rate booster.*

bit, and no parity. The start bit is needed for synchronisation purposes, and it indicates to the receiving circuit that a byte of data is about to commence. The receiving circuit can then determine the logic level of each bit by sampling the signal at the appropriate times. As the start bit is the only synchronisation signal, it is essential to the correct operation of the system that the transmitting and receiving baud rates correctly match, and the use of standard baud rates is an essential part of any asynchronous serial system. It is the least significant bit that is transmitted first, running through in sequence to the most significant bit. The stop bit is not really a bit of information at all, and it is just a period during which signal stays at its quiescent level. This is presumably to set a minimum spacing between bytes of data, so that the receiving equipment has time to process one byte before commencing reception of the next one.

On the face of it a baud rate converter merely has to clock data into a shift register at the appropriate rate, and then clock it out again at the new rate. In practice matters are not quite this simple, as the shift register cannot simultaneously clock data in at one rate and clock it out again at a different rate. It is therefore a matter of receiving complete bytes, transferring them in parallel form from one shift register to another, and then transmitting them in serial form from the second shift register. For this reason the transmitted signal is delayed slightly in comparison to the received signal. Because the transmission rate is higher than the reception rate there are larger gaps between the bytes on the transmitted signal than there are on the received signal. Fortunately, neither the delay nor the increased gaps are of any practical consequence.

Note that there is no difficulty in producing an increase in baud rate, but a conversion in the opposite direction is much more difficult. The problem is simply that data would often be received faster than it could be transmitted. This could be overcome by having a buffer to store accumulated bytes of data, but this would obviously require a relatively complex circuit, and the relative timing of groups of bytes could be significantly altered. This makes such a system a less attractive proposition from the MIDI interfacing standpoint.

SYSTEM OPERATION

Asynchronous serial reception and transmission is simple in theory, but in practice it generally requires some complex circuitry. Things are greatly simplified by the availability of special serial interface devices, and for a stand–alone unit of this type a UART (universal asynchronous receiver/transmitter) is the most suitable type. A UART forms the basis of this unit, as can be seen from the block diagram of Fig.2.

The UART can be programmed via five inputs to operate with any of the standard word formats, and it provides all the necessary logic for serial to parallel and parallel to serial data conversion. A level shifter/inverter stage is needed at the input in order to give an input to the UART that is at suitable votages (normal 5 volt logic levels) and of the correct phase. The transmission and reception baud rates are controlled by separate clock oscillators, and the clock frequency must in both cases be at sixteen times the required baud rate. The clock signal for the receiver is derived from a 2.45MHz crystal oscillator (or 2.4576MHz to be precise), and this drives the receiver section of the UART via a buffer stage and a divide by 8/16 circuit. The latter is switched to give 9600 or 19200 baud as desired. On the transmitter side a 500kHz oscillator based on a ceramic resonator drives the UART via a buffer stage. The serial output signal is fed to an inverter and then to an open collector driver stage which provides the output signal.

Decoded bytes are fed in parallel form from the receive to the transmitter, but some simple logic circuitry is need to ensure that received bytes are actually transmitted. A status output on the receiver section of the UART goes high when a complete byte has been received, and this flag can be reset by taking an input terminal low. In this circuit the signal from the status output is inverted and used to reset itself. A delay circuit is included in order to lengthen the pulse from the status output, so that it can reliably operate an input on the transmitter section of the UART. This input is used to initiate transmission of the byte currently on the parallel inputs, which is, of course, the byte just decoded by the receiver. Thus, as soon as a byte is received it is transferred to the transmitter and clocked out on the serial output.

THE CIRCUIT

The full circuit diagram for the RS232C to MIDI converter appears in Fig.3. Taking the receiver section first, the level shifter/inverter circuit is a simple common emitter switch based on TR3. The clock oscillator is a conventional crystal type based on TR1, and having TR2 as a common emitter buffer/amplifier which ensures that the output signal is at a high enough level to drive a logic input properly. IC1 is a

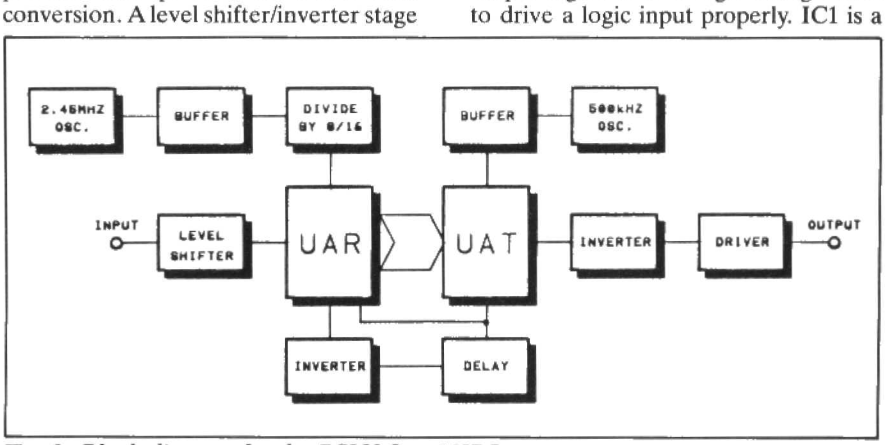


Fig. 2. *Block diagram for the RS232C to MIDI converter.*

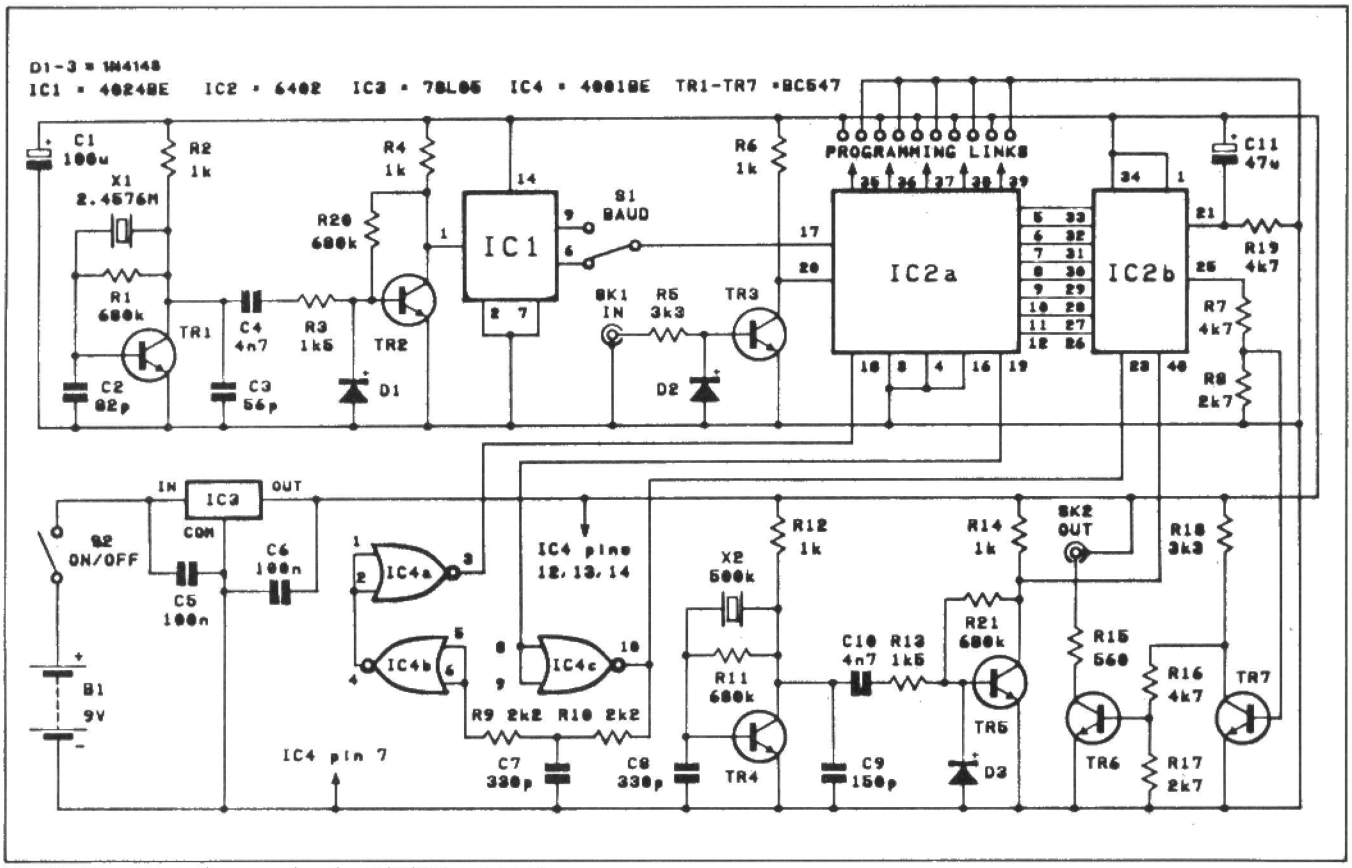


Fig. 3. *The circuit diagram for the RS232C to MIDI converter*

CMOS 4024BE 7 stage binary ripple counter, but in this case only three or four stages are used, depending on the setting of the baud rate switch, S1. Pin 9 of IC1 gives the divide by 8 action (19200 baud), while pin 6 gives the divide by sixteen action (9600 baud). C11 and R19 provide a positive reset pulse to the UART(IC2) at switch–on.

Turning to the transmitter section, TR7 inverts the serial output signal so as to give an output signal of the correct phase, and TR6 is the output transistor. R15 provides current limiting at approximately the required level of 5 milliamps. The clock oscillator and buffer stage are essentially the same as those used in the receiver section, but the oscillator is based on a ceramic resonator rather than crystal, and the "tuning" capacitors (C8 and C9) have been made higher in value due to the much lower operating frequency of this oscillator.

The control logic is very simple, and is based on three of the gates in a CMOS 4001BE quad 2 input NOR gate (IC4). All three gates are connected to operate as inverters in this circuit. IC4c inverts the signal from the received data status flag, and it drives the reset input for this flag via a basic C–R timer circuit comprised of R10 and C7. IC4a and IC4b are used as a non–inverting high gain buffer which provides the reset input with a drive signal at proper logic levels. The stretched reset pulse is available from both IC4a and IC4c, but it is IC4c which is used to drive the TRRL (transmit buffer register load) input of IC2.

A 5 volt supply is required, and this is derived from a 9 volt battey via monolithic voltage regulator IC3. The current consumption of the unit is around 20 milliamps or so, and a fairly high capacity 9 volt battery (such as six HP7 size cells in a plastic holder) should be used as the power source. If the computer has a +5 volt output, then there would probably be no difficulty in omitting B1, S1, IC3, and C5, and using the computer to power the circuit.

CONSTRUCTION

Details of the printed circuit board are shown in Fig.4. The three DIL integrated circuits are all MOS types. Accordingly, they should all be fitted in holders and the other standard anti–static handling precautions should be observed. The circuit was designed to have an industry standard 6402 UART in the IC2 position, but the virtually identical AY–3–1015D (which is generally a little less expensive) also seems to work properly in the unit. On the prototype X1 is an HC–33/U type, which means a wire–in type with 12.7 millimetre lead spacing. A smaller wire–in type such as an HC–18/U type could probably be fitted onto the board without too much difficulty, but other types are unlikely to be suitable, and the correct (HC–33/U) type is definitely preferable.

The five link wires close to pins 35 to 39 of IC2 program the word format, and fig.4 shows the correct wiring for the MIDI format of eight data bits, one stop bit, and no parity (all asynchronous serial systems use one start bit). Obviously other word formats are irrelevant in a MIDI application since the reception and transmission word formats of this unit must be the same. The circuit could be modified to use separate UARTs so that different transmission and reception formats could be used, but this is again of little use in the present context where only 8 bit formats are usable. For anyone using the unit as the basis of a baud rate converter for other purposes the ability to program the unit for different word formats is much more useful. Table 1 gives details of the word formats available, and the logic levels needed at the five programming inputs for each of the available formats.

The prototype is housed in a case which has approximate outside dimensions of 170 by 145 by 55 millimetres, but it should be possible to squeeze everything into a somewhat smaller case if desired. The controls and sockets are mounted on the front panel, and the printed circuit board is mounted on the base panel well to the front of the unit. This leaves space for the battery towards the rear of the case. If six HP7 cells in a plastic holder are used as the power source the battery connector should be a standard PP3 type. Fig.4 shows the correct method of connection to the output socket (SK2). On the prototype the chassis of SK2 is earthed to the negative supply rail via the metal

front panel and the earth lead of SK1. If this connection is not provided by way of the front panel a link wire should be added between the chassis tag of SK2 and the earth tag of SK1. This lead does not carry the output signal, but it is needed to earth the screen of the output cable so that no significant radio frequency interference is radiated from the cable. I used a 3.5 millimetre jack socket for SK1, but this could be changed for any type of connector which you consider more convenient with your particular set up. The standard RS232C connector is a 25 way 'D' type, but the cost of one of these is not really justified when only two lines are implemented.

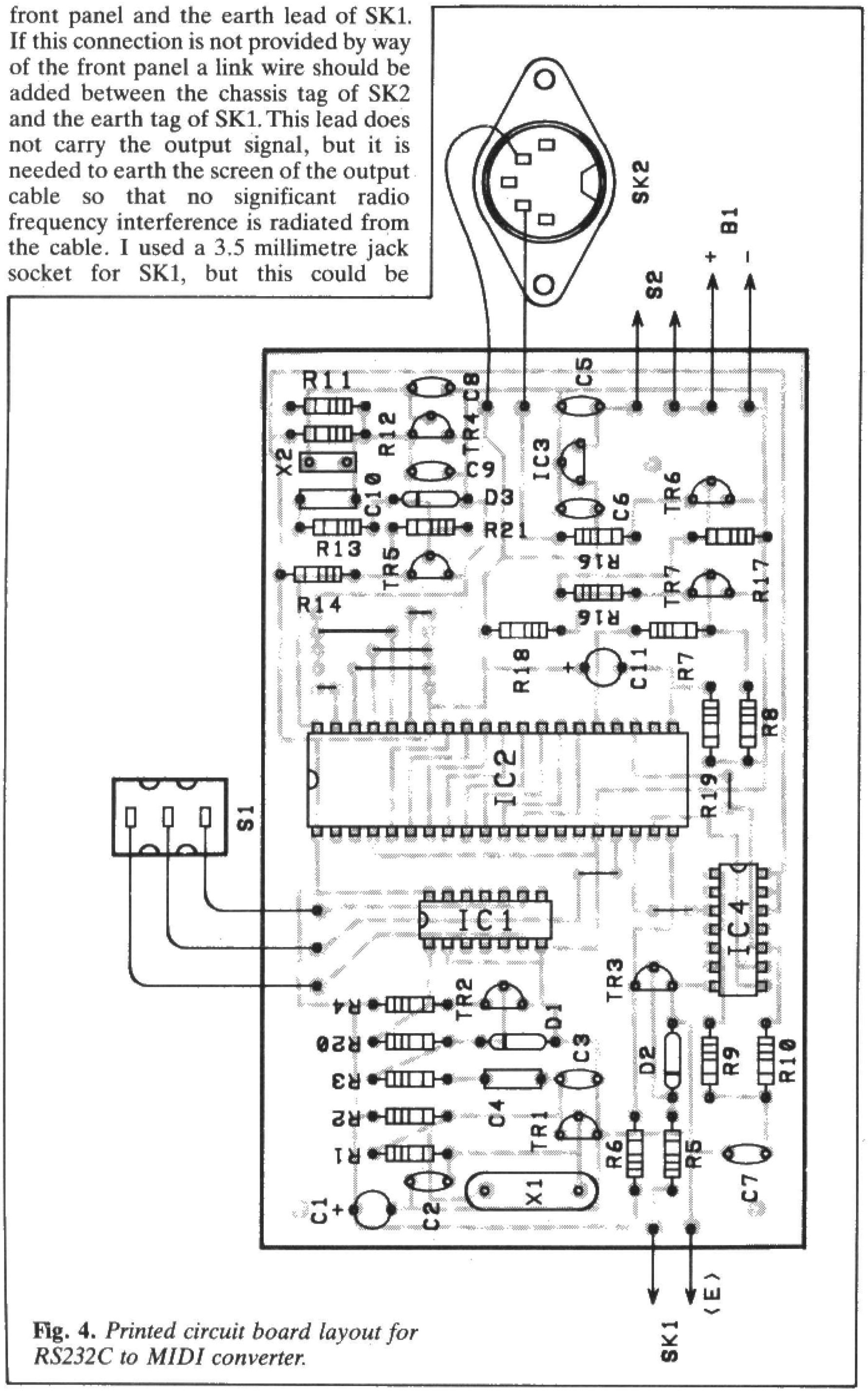


Fig. 4. *Printed circuit board layout for RS232C to MIDI converter.*

IN USE

The output couples to the MIDI instrument via a standard MIDI lead (i.e. pins 4 and 5 of one plug connect to pins 4 and 5 respectively of the other plug). Only the signal earth and transmitted data terminals of the RS232C (or RS423) port are used. With some computers the CTS (clear to send) handshake input must be taken to the active state before the port can be persuaded to output any data. If this should prove to be the case, simply linking the CTS and RTS terminals should give the desired results. In most cases though, the handshake lines can simply be ignored.

Before the unit can be tested, the computer's serial interface must be set to the correct word format and baud rate, and there are usually operating system commands to facilitate this. With the BBC model B for example, the word format defaults to the correct eight data bits, one stop bit, and no parity. The operating system commands *FX8,7 and *FX8,8 select transmission rates of 9600 and 19200 baud respectively. If only an eight data bits and two stop bits format is supported, this should give perfectly satisfactory results. Where the higher baud rate is supported it is probably best to opt for this one, as it permits better synchronisation of notes in chords. However, if the unit is driven from a BASIC program, it is likely to be the speed of the program rather than the serial port that limits the rate at which data can be transmitted. Acorn do not guarantee reliable operation at 19200 baud, but I experienced no difficulties when using this rate.

With most computers the operating system provides some way of directing data to the serial port, but where possible it is generally better to write data direct to the serial interface hardware. For instance, with the BBC

COMPONENTS

RESISTORS

R1, R11, R20, R21	680k (4 off)
R2, R4, R6, R12, R14	1k (5 off)
R3, R13	1k5 (2 off)
R5, R18	3k3 (2 off)
R7, R16, R19	4k7 (3 off)
R8, R17	2k7 (2 off)
R9, R10	2k2 (2 off)
R15	560

All ¼W 5% carbon or better.

CAPACITORS

C1	100µ 10V radial elect
C2	82p ceramic plate
C3	56p ceramic plate
C4, C10	4n7 polyester layer (2 off)
C5, C6	100n ceramic (2 off)
C7, C8	330p ceramic (2 off)
C9	150p ceramic plate
C11	47µ 10V radial elect

SEMICONDUCTORS

IC1	4024BE
IC2	6402 or AY-3-1015D
IC3	uA78L05 (+5V 100mA reg)
IC4	4001BE
TR1 to TR7	BC547 (7 off)
D1, D2, D3	1N4148 (3 off)

MISCELLANEOUS

SK1	3.5mm jack
SK2	5 way (180 degree) DIN socket
S1	SPST sub-min toggle
S2	SPDT sub-min toggle
X2	500kHz ceramic resonator
B1	9 volt (e.g. 6 x HP7 in holder)

Printed circuit board, case about 170 x 145 x 55mm, 14 pin DIL i.c. holder (2 off), 40 pin DIL i.c. holder, battery connector, stand-offs, wire, pins, etc.

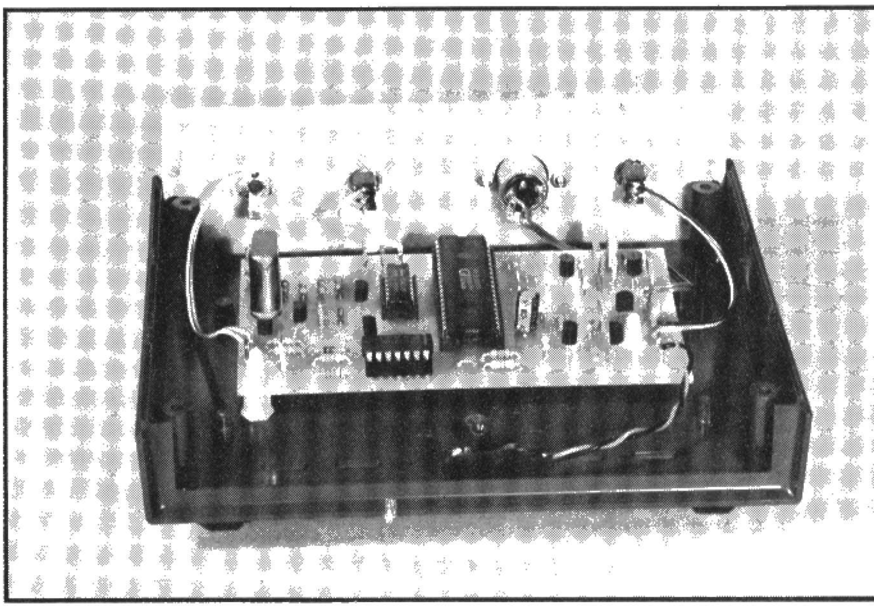
CONSTRUCTOR'S NOTE:
The PCB may be bought through the PE PCB Service. A full kit of parts is available from Magenta.

TABLE 1

6402 WORD FORMATS

PIN Number 35	36	37	38	39	Data Bits	Parity	Stop Bits
L	L	L	L	L	5	ODD	1
L	H	L	L	L	5	ODD	1.5
L	L	L	L	H	5	EVEN	1
L	H	L	L	H	5	EVEN	1.5
H	L	L	L	X	5	NONE	1
H	H	L	L	X	5	NONE	1.5
L	L	L	H	L	6	ODD	1
L	H	L	H	L	6	ODD	2
L	L	L	H	H	6	EVEN	1
L	H	L	H	H	6	EVEN	2
H	L	L	H	X	6	NONE	1
H	H	L	H	X	6	NONE	2
L	L	H	L	L	7	ODD	1
L	H	H	L	L	7	ODD	2
L	L	H	L	H	7	EVEN	1
L	H	H	L	H	7	EVEN	2
H	L	H	L	X	7	NONE	1
H	H	H	L	X	7	NONE	2
L	L	H	H	L	8	ODD	1
L	H	H	H	L	8	ODD	2
L	L	H	H	H	8	EVEN	1
L	H	H	H	H	8	EVEN	2
H	L	H	H	X	8	NONE	1
H	H	H	H	X	8	NONE	2

H = High, L = Low,
X = either state will do.



model B the transmit register of the 6850 ASCIA used as the basis of the RS423 port is at address &FEO9. Any values written to this address will therefore be transmitted from the serial port.

Initially a simple test routine should be tried. Staying with the BBC model B as our example computer, this simple program enables note values to be entered, and then it switches on the appropriate note for about one second.

```
10 INPUTA
20 ?&FEO9 = 145
30 ?&FE09 = A
40 ?&FE09 = 63
50 FOR D = 1TO 1000: NEXT
60 ?&FEO9 = 129
70 ?&FEO9 = A
80 ?&FEO9 = O
90 GOTO 10
```

There is insufficient space available here for information on MIDI software codes, but this has been fully covered in a separate article anyway (PE Sept 87). Even a relatively inexperienced programmer should have no difficulty in producing a simple step–time sequencer to enable a short repetitive backing track to be produced. It is not too difficult to write a program that enables quite long sequences to be produced, but when using a Basic program it is advisable to use no more than about four channels. Machine code assembly language enables more channels to be sequenced without there being any apparent lack of synchronisation between channels, but a software hold–off must then be used to prevent data being written to the serial port at an excessive rate. Obviously the greater your knowledge of your computer's hardware and the finer your programming skills, the better your prospects of fully exploiting the interface PE

SEMICONDUCTORS

PART 2 : DISCRETE DEVICES
BY ANDREW ARMSTRONG

Junction transistors and long-tailed pairs

The second part of our series on semiconductors looks at the characteristics and applications of small signal transistors and power transistors, at low and high frequencies.

In part one we looked at the principles governing silicon semiconductor devices, and got as far as some practical information on some currently available types of diode. In this part we shall look at how to choose and use junction transistors. In general the coverage, though not exhaustive, should be adequate for almost all amateur design and constructional purposes. Inevitably some potentially interesting topics are not covered; to cover everything would take a whole book. In particular, I shall not delve deeply into the subject of RF, which is a specialised topic in itself.

REAL JUNCTION TRANSISTORS

Junction transistors are classified in many different ways according to their intended function. We have small signal and power devices, and we have transistors intended for various different frequency ranges, right up to microwaves. In general, the higher frequency transistors are perforce of a lower power rating, because of the charge storage time and junction capacitance associated with power transistors.

Before looking closely at esoteric transistor types, let us consider transistors of the types normally used in amateur construction projects. With the exception of specialised items such as amateur radio transmitters, etc., four major classifications of transistor are used: npn and pnp small signal transistors, and npn and pnp power transistors. This may seem to be an over–simplification, but in fact, many designs which specify a particular type of transistor do so because the designer had that type available at the time, even though a range of other type numbers might be suitable.

By far the most commonly used type is the small signal npn transistor. Many different varieties exist, optimised for such things as low noise, high gain at low collector currents, low saturation voltage and so on. Most amateur construction projects however do not utilise the special characteristics but are designed around a "vanilla" transistor. This mythical device represents the lowest common denominator for a wide range of transistor type numbers. This vanilla specification is shown in Tables 3 and 4 along with the specifications of several other ordinary and not so ordinary transistors. The logical conclusion from this is that in most amateur construction projects any npn transistor from the BC107/BC182/BC237 families will work perfectly well. Clearly an element of judgement must be applied, for example if a higher than normal voltage is used in the circuit a particular transistor type may have been chosen because of its collector voltage rating. Normally however, the author will mention this in the text if it is so.

As well as the basic type number of a transistor, a suffix is often specified. For example, a design may specify a BC183L rather than a BC183. The only difference between the standard and "L" type transistors is that the "L" type has a differeent pin layout. Specifically the pin connections for the "L" type are in the order B–C–E rather than the more familiar C–B–E. If the wrong type is available, it is usually no problem to bend the legs to fit the PCB, and if necessary special pads are available to form "L" type leads to the more normal configurations. Admittedly, most home constructed projects do not use transistor pads, but they can be helpful sometimes.

There is one transistor I know of which has different specified electrical characteristics in its "L" type form. The BC214LB has a higher gain at high collector currents than the BC214, accord-

Table 3 – NPN Junction Transistors

Type No.	Vcbo (max) V	Ic (max) mA	Hfe@ typ	If mA	f_t MHz	Complement	Ptot W	Package	COMMENTS
BC107	50	100	110	2	150		0.3	TO18	
BC108	30	100	120	2	150		0.3	TO18	
BC109	30	100	180	2	150		0.3	TO18	
BC109C	30	100	420	2	150		0.3	TO18	
BC182	60	200	125	2	150	BC212	0.3	TO92	
BC182B	60	200	240	2	150	BC212B	0.3	TO92	
BC183	45	200	125	2	150	BC213	0.3	TO92	
BC184	45	200	240	2	150	BC214	0.3	TO92	
BC237	50	100	125	150	150	BC337	0.3	TO92	BC237,238,239 are TO92 "L" type versions of BC107 etc. BC307 etc are TO92 normal pin connection versions
BF259	300	100	25	30	25		0.5	TO39	Sometimes used as CRT drivers.
BF480	20	20	G^{tr}	15db	2000 type		0.2	SOT37	Possibly the fastest easily available transistor.
BFY51	60	1A	49	150	50		0.8	TO5	
BFY90	30	50	25	2	1000		0.2	TO72	
BSX20	40	500	40	10	500	2N2906	0.36	TO18	Very fast switching.
ZTX450	60	1A	100	150	150	ZTX550	1W	E line	Good saturated switching.
ZTX650	60	2A	100	500	100	ZTX750	1W	E line	Excellent saturated switching.
ZTX653	120	2A	100	500	100	ZTX753	1W	E line	
2N2219	60	800	100	150	300		0.8	TO5	
2N2369	40	500	40	10	500	2N5771	0.36	TO92	Like BSX20
2N3904	60	200	100	10	300	2N3906	0.5	TO92	
BD131	70	3A	20	150	60	BD132	15W	TO126	
BD139	80	1.5A	40	150	–	BD140	12.5	TO126	
BD787	80	4A	10	200	50	BD788	15W	TO126	Ideal for small switched mode supplies
TIP31	80	3A	20	500	3	TIP32	40W	TO220	TIP31A is rated at 100V, B at 120V, C at 140V
TIP33	80	10A	20	500	3	TIP34	80W	TO218	A, B, C ratings as TIP31
TIP121	80	5A	1000	3A	≈0.1	TIP126	65W	TO220	Darlington power transistor. The device includes two base-emitter resistors and an antiparellel diode between collector and emitter.

Table 4 – PNP Junction Transistors

Type No.	Vcbo (max) V	Ic (max) mA	Hfe@ typ	If mA	f_t MHz	Complement	Ptot W	Package	COMMENTS
BCY70	50	200	50	10	250		0.35	TO18	
BC212	60	200	60	2	200	BC182	0.3	TO92	BC212A has hfe of 100, B has hfe of 200
BC213	45	200	80	2	200	BC183	0.3	TO92	A and B versions as BC212
BC214	45	200	140	2	200	BC184	0.3	TO92	BC214B has hfe of 200, C has hfe of 350
BC337	50	800	100	100	60	BC237	0.36	TO92	
ZTX550	60	1A	100	150	150	ZTX450	1W	E line	Good saturated switching
ZTX750	60	2A	100	500	75	ZTX650	1W	E line	Exc saturated switching
2N2907	60	600	100	150	200		0.4	TO18	Switching
2N3906	40	200	199	10	250	2N3904	0.5	TO18	Switching
2N5771	15	50	40	50	850	2N2369	0.625	TO92	Fast switching
BD132	45	3A	20	150	60	BD131	15W	TO126	
BD140	80	1.5A	40	150	150	–	12.5	TO126	
BD788	60	4A	10	200	50	BD787	15	TO126	
TIP32	80	3A	20	500	3	TIP31	40	TO220	A, B, C types as TIP31
TIP34	80	10A	20	500	3	TIP33	80	TO218	A, B, C types as TIP33
TIP126	80	5A	1000	3A	0.1	TIP121	65	TO220	Darlington power transistor. The device includes two base-emitter resistors and an antiparallel diode between collector and emitter.

ing to a rather old data book. I cannot be sure it is not a misprint, but in any case the difference is slight.

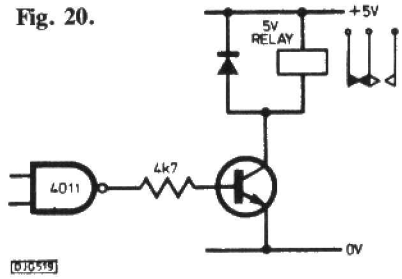
The suffixes "A," "B," and "C" do relate to different electrical characteristics, normally gain. The standard version of a transistor usually has a very wide gain tolerance, for example 100 to 900. The "A," "B," and "C" versions are selected to gain in three bands, generally covering no more than a 2:1 range. If a BC182B is specified for a project, it could well be because a medium gain transistor is required. If there is nothing else special about the circuit, any small signal npn transistor in the correct gain range will work. Note, though, that not all transistor types are banded in the same gain ranges, so it is necessary to check that any substitute transistor falls in the range required by the circuit.

CRITICAL PARAMETERS

In general it should always be possible to use a transistor with a higher specification in whatever aspect of the spec is important as a replacement for the specified type. If this is not possible, for example if a transistor with too high a gain would cause problems just as would a transistor with too low a gain, then one may often (but not always) conclude that the circuit design is at fault. It is normal to design transistor circuitry so that the passive components around the transistor limit the gain, frequency response etc. This requires a transistor whose specification is significantly better than that being set by the passive components. For example, to make a video amplifier with a frequency response of 20MHz, it is preferable to use transistors with a cutoff frequency ft of at least 100 MHz, preferably 200 MHz.

Fig. 20 shows an example of a circuit in which the choice of transistor type is

Fig. 20.



important. At first sight, one would expect an ordinary vanilla transistor to do the job, but closer inspection shows us that the gain of such a transistor in or near saturation would not be high enough to pass enough current to switch on the relay. A ZTX450 is specified. This transistor has extremely good saturation characteristics and is optimised for switching. Even in this case there are equivalents. Any transistor from the ZTX450 or 650 range would work; there are no doubt several "2N" types which would do and in fact even a small n–channel power f.e.t. would do the job. A BC182 however would work in about a third of the units constructed. This is the sort of aspect that an author would usually mention.

So far we have considered only npn small signal transistors. The same reasoning applies to small signal pnp types, and indeed many common npn transistors have a pnp complement. Often though the pnp transistor has a slightly lower specification in one aspect or another, as Table 3 shows.

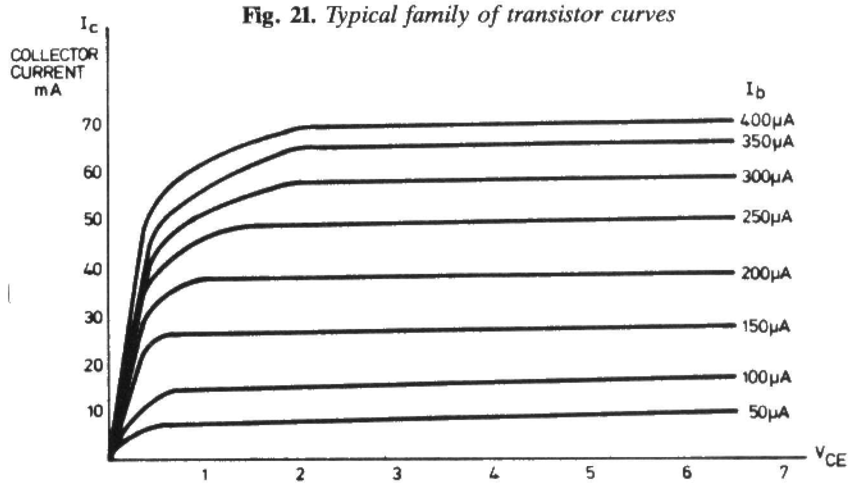
The operating characteristics of transistors are often illustrated by a family of curves of collector current against collector voltage at the various different levels of base current. So common is this representation that transistor curve tracers are produced to show on an oscilloscope screen just such a family of curves. A typical family of curves for a small signal npn transistor is shown in Fig.21. As the graph shows, at low values of collector–emitter voltage the gain of the transistor is reduced. This effect is more pronounced at higher levels of collector current. From this family of curves it is clear to see that the specified gain of a transistor does not apply under all circumstances.

This dependence of gain on collector current has another effect as well. If the transistor is used to amplify a signal which requires wide excursions of collector current, then distortion due to the non–linearity will occur unless the design is carefully arranged to avoid this. Generally this will involve using local negative feedback, and in the case of an audio amplifier overall negative feedback would be used as well.

BIAS

To use a transistor in a linear circuit it is necessary to bias it correctly. One might imagine that the way to bias a transistor would be to feed the base with a current of $1/h_{fe}$ times the required col-

Fig. 21. *Typical family of transistor curves*



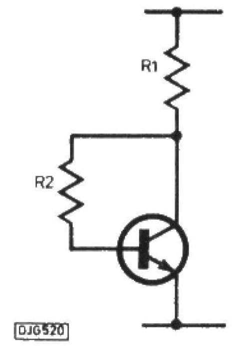


Fig. 22.

lector current. This would work in a limited fashion, but because the gain of a transistor varies from sample to sample of the same type of device, and also varies with current, voltage, and temperature, this method of biasing is not usually appropriate. The biasing scheme shown in Fig. 22 shows the nearest thing to this idea which is at all stable or reproducible.

In this circuit, the value of R1 is calculated to drop half the supply voltage at the required quiescent collector voltage is equal to half the supply voltage. The value of R2 is then calculated so that it passes the nominal required bias current when fed with half the supply voltage. If the gain of the transistor is higher than nominal, the effect is partly compensated by the fact that the collector voltage is lower and therefore the bias current is lower. This stabilising action can compensate for modest variations of gain from the nominal, but wide variations will set the collector voltage outside a reasonable operating range.

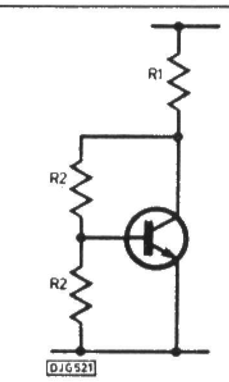


Fig. 23.

Fig.23 shows an improvement upon this idea in which the transistor's collector voltage is potted down by R2 and R3, so that at the nominal collector voltage, the voltage at the junction of R2 and R3 is approximately 0.65V. In order that the base current drawn by the transistor does not upset this condition too much, the current flowing through R2 and R3 is normally chosen to be at least ten times the anticipated base current. This can lead to a relatively low input impedance, but the stability and reproducibility of the bias point is much better than that of the circuit of Fig.21. On the other hand, the circuit of Fig.21 will provide the maximum amplification in a simple stage for low level signals.

STABILISATION

Neither of these two configurations represents the ultimate instability, and they also suffer from non–linearity. The circuit shown in Fig. 24 represents a significant improvement in terms of both bias point stability and linearity. This circuit is widely used as a standard single stage audio gain block when discrete transistors are used. The addition of the emitter resistor, R4, is responsible for the improved d.c. stability. Its value is usually chosen so that it drops about one volt at the nominal emitter current of the transistor. This tends to swamp out any changes in Vbe due for example in changes in temperature.

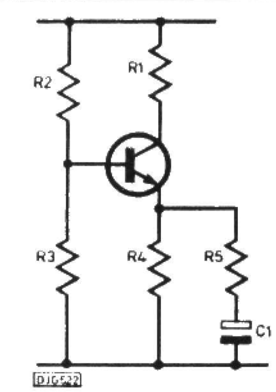


Fig. 24

The values of R2 and R3 are chosen to set the base voltage at approximately 1.65 volts. If R5 and C1 were omitted from the circuit it would work perfectly well in this form, and the voltage gain would be set by the ratio of R4 and R1. If the stage were to be run on a 9V battery, at a current of 1mA, one would probably have a value for R4 of 1k, and for R1 of 3k9, which would give a voltage gain of approximately 4. In many cases a higher a.c. gain would be required. The way to obtain this without compromising d.c. stability is to lower the a.c. emitter resistance, so we add R5 and C1, in parallel with R4. The gain can then be set to any value which the transistor is capable of providing.

There is one disadvantage to higher gain. When a signal is applied to the base of the transistor, the base current varies, and therefore the base/emitter voltage varies, as shown by the diode curves in part 1. This inevitably causes some non–linearity, but so long as the greater part of the signal voltage appears across the emitter resistance, rather than the base/emitter junction, the non–linearity is minimised. However, if a low value is chosen for R5, little signal voltage will appear across the emitter resistor, and the non–linearity will be more pronounced.

INPUT RESISTANCE

The higher the gain of the transistor, the less non–linearity which will be introduced in any given circumstance. To see why this is so, consider the case of a very low gain transistor. The base current will be high, and a significant proportion of the current flowing in the emitter resistor will be from the base terminal rather than the collector terminal. Thus, the change in base current for a given signal will also be substantial. On the other hand, a transistor with an extremely high gain would have very low base current, so the change in current for a given signal would be negligible.

This affects the apparent input impedance. If the gain of the transistor is 99, then 100 times as much current flows in the emitter resistor as in the base. These same proportions apply to any change in base current (excepting non–linearities) so the change in emitter voltage is one hundred times as much as would occur from the base current alone. The impedance looking onto the base of the transistor is therefore one hundred times the emitter resistance (including any extra resistor in series with a capacitor in the case of a.c. signals).

Several configurations exist to provide more gain. Fig.25 shows a darlington configuration. In this two transistors are used in such a way that their current gains multiply. If each one has a gain of 100, then one microamp fed into the base of Q1 would result in an emitter current of 101μA, most of which is fed into the base of Q2. The emitter current of Q2 will be 101 times as much again so that the overall current gain would be approximately 10,000. In practice, not all this gain would be realised because a significant current must be bled away by R1 to allow the stage to switch off reasonably fast when the base current of Q1 is stopped. If the value of R1 is too high, then the charge storage in the base of Q2 does not start to decay until Q1 has completely switched off, so that the transistor switching delays are additive. On the other hand, too low a value for R1 results in too low a gain, so that a compromise has to be found. Generally speaking, in an application for which a darlington configuration is required, it will be clear whether gain or switching speed is more important.

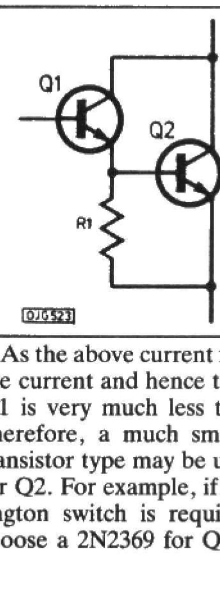


Fig. 25.

As the above current figures illustrate, the current and hence the dissipation in Q1 is very much less than that in Q2. Therefore, a much smaller and faster transistor type may be used for Q1 than for Q2. For example, if a particular darlington switch is required, one might choose a 2N2369 for Q1, and a BD139

for Q2. Suitable combinations of transistors may be chosen for other specific requirements, but it is often more convenient to use a ready–made darlington transistor which may well include R1 and an anti–parallel protection diode across the collector and emitter of Q2. In such a device, the transistor characteristics will have been optimised for the purpose intended.

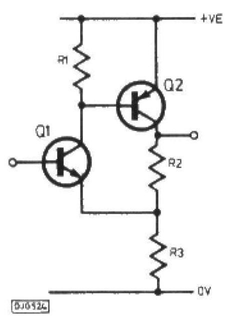


Fig. 26.

VOLTAGE GAIN

In Fig. 26 we have a configuration which can increase both current and voltage gain. As with simple op amp circuits, the gain is approximately set by the ratio of the feedback resistors, R2 and R3. Clearly, the signal on the emitter of Q1 will be similar to that on the base, at a d.c. level approximately 0.65V lower. If the values of R2 and R3 are low enough that most of the current in them comes from the collector of Q2 rather than the emitter of Q1, then the two resistors form a potential divider from the collector of Q2, and hence the voltage of the collector of Q2 must be whatever would be required at the top of such a potential divider as to give the aforementioned signal on the emitter of Q1.

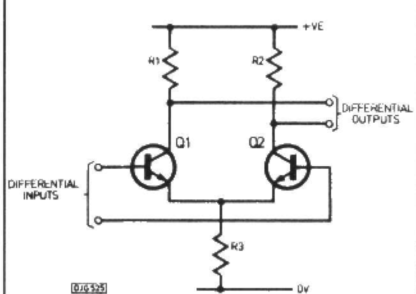
In order that the ratio of R2 and R3 shall be the main determining factor on the gain of the stage, we must arrange that the current in Q2 is much greater than the current in Q1. A good place start is by determining the required output impedance which is equal to R2 plus R3. Once this has been determined we can calculate the collector current required for Q2 to maintain the output voltage at approximately half the supply voltage. If we then arbitrarily decide that the current in Q1 shall be a tenth of this, we can calculate the value of R1 to drop approximately 0.65V at the collector current of Q1.

The feedback via R2 and R3 will tend to regulate the current in Q1 to the level decided. This calculation so far only gives an approximation because ten per cent of the current in R3 comes from Q1, rather than from Q2, but in practice a little trial and error will be required to chose the exact component values anyway, because of the need to stick to preferred resistor values. This type of circuit can give, for example, reasonable gain at audio frequencies, with acceptable linearity.

A TRICK OF THE TAIL

A discussion of transistor circuits would not be complete without mention of the long tailed pair. This configuration among its many uses forms the basis of op amp designs. The principle of operation is very simple. The voltage across R3 is more or less constant, and therefore the current through it is more or less constant (sometimes a constant current is shared between Q1 and Q2, according to their relative base voltages. If, as is usually the case, R1 and R2 are chosen to have equal values, then the output voltages are in direct proportion to the current sharing. (Fig. 27).

Fig. 27.



In this circuit configuration, as with that of Fig. 22, the precise voltage gain is not defined. It depends upon the change in collector current of the transistor per unit change in base voltage. This parameter is referred to as the mutual conductance, represented by the symbol g_m. It is not a parameter which is usually specified for junction transistors, because the junction transistor works in such a way that the g_m is not usually a meaningful parameter. Because of the shape of the base emitter conduction curve, and the relatively constant current gain, g_m is heavily dependent upon current. In the case of valves and f.e.t.s, g_m is specified and is much more meaningful.

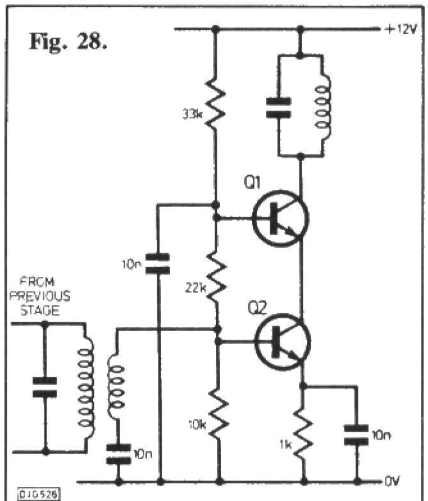
For the long tailed using pair using junction transistors, however, it is normal to operate the transistors in such a way that there is plenty of gain, and then use external feedback to set the gain of the stage. On ICs, where the transistor parameters can be carefully controlled and matched, the gain of a long tailed pair may more readily be defined, but this is not of concern to the home constructor.

HIGH FREQUENCY CIRCUITS

If transistors are to be used at high frequencies, another factor becomes significant. Because the collector/base junction of a transistor is a large flat area, it possesses significant capacitance. At high frequencies, this capacitance can couple the signal from the collector directly into the base region. Unfortunately, the signal on the collector is inverted relative to the signal on the base, so this stray coupling tends to fight the intended operation of the transistor, particularly if rapid switch off is desired. Several methods have been tried to minimise this effect, for example tuning or neutralising components, but one of the most successful is the cascode configuration.

In the cascode configuration, one transistor is called upon to provide current gain, and the other to provide voltage gain. In the circuit shown in Fig. 28, the signal is fed in to the base of Q2. Because the collector of Q2 is maintained at an almost constant voltage by the way in which Q1 is biased, the collector/base capacitance (sometimes referred to as Miller capacitance) has no signal which it can spuriously couple to the base. Therefore, the transistor can operate very fast.

Fig. 28.



Q1 provides the voltage gain, but its base is decoupled, and the signal is fed in to the emitter as a varying current. Again, the effects of collector/base capacitance can do little to interfere with correct operation. Even though there is a signal voltage on the collector, this can do little to resist the switch off of the transistor once the emitter current has ceased. Current flow in the upper transistor once the emitter current has ceased. Current flow in the upper transistor can continue for a brief period, as charge is removed from the base, but this base current results in no emitter current. All the collector current flows out of the base and thus depletes the charge in the region very rapidly.

Not only is this configuration very effective to gain the best high frequency performance, but it can also circumvent the problem of spurious oscillation due to signal coupling via the collector/base capacitance. This type of configuration is widely used in critical RF, video, and switching circuits. It also illustrates the principle of the dual gate m.o.s.f.e.t., so we shall return to it later.

Here endeth the second lesson. Part three will cover linear power and f.e.t.s.

RECALLING HISTORY

PART ONE BY BARRY DRAKE

1854 CALLING 1987!

If someone told you that a man name Bell would invent a machine which would still be ringing everywhere in the world a century later, what would you say? Good story, eh? Well, here it is...

If readers were asked to design a telephone system using the latest electronic technology, there would be a great many differing approaches to the project. What is certain is that none of them would resemble the system operated by British Telecom today. With a little thought, it is evident that the present system was not designed as such, but is the result of one hundred years of evolution!

Let's look at it another way: I have a pre–war post–office telephone – one of those heavy black instruments with a drawer in the base to contain a selection of telephone numbers. I can take this museum piece, and I can connect it to the Telecom system without modification, and make and receive calls on it. Quite something! Especially when you consider that I can talk to you while you walk around your garden using the very latest cordless instrument. And neither of us will be at a disadvantage with our particular telephone.

The story begins in the middle of the last century with a paper published by Charles Bourseuil, a Frenchman, in 1854, suggesting that sound might be conveyed by wire. The idea was proved by Philip Reis of Frankfurt in 1861 when he succeeded in producing a crude device for transmitting sound by wire using a diaphragm fitted with a contact to make and break a circuit at the frequency of an acoustic signal. This was used in conjunction with an electromagnetic receiver and a battery, and served only to verify Bourseuil's theory, as the signal produced was barely recognisable as speech. In 1876, Alexander Graham Bell, of Edinburgh, although at the time living in America, made two electromagnetic transceivers of a design which was similar to the receiver used subsequently on telephones throughout the world. We've all tried using two headphone or telephone ear–pieces connected together with a long length of twin flex. One person speaks into one device while the other listens to the one at the other end. This is exactly what Bell did. The speech transmitted is faint but usable – but clearly would not stand up to the loss which long lines would occasion, and of course there were no electronic amplifiers around to solve that problem the easy way.

At the same time as Bell performed his famous experiment, Gray from Chicago is said to have carried out work independently, and along very similar lines.

NAIL MICROPHONE

A year later, Edison, seeing the great possibilities of Bell's work, solved the problem of lack of signal strength, by his invention of the carbon microphone, (or transmitter as it was then called). The theory behind the carbon transmitter came just a year later during 1878 in a paper produced by Professor Hughes for the Royal Society. He showed that any system of loose contacts can be used as a transmitter (he used three iron nails to demonstrate the theory) and in the same paper used for the first time the word microphone. Over the next few years the carbon microphone was developed into a form identical in all except outward appearance to that still in operation in many telephones today. Thus was established around one hundred years ago, the first of the criteria for the communication system which we use today: that a current of between 25mA and 200mA DC needs to be provided into a loop resistance of some 500 ohms. This represents the 40 ohms or so of the microphone, plus the line and transformer resistances, and all because the first transmitters had a optimum working point in that area.

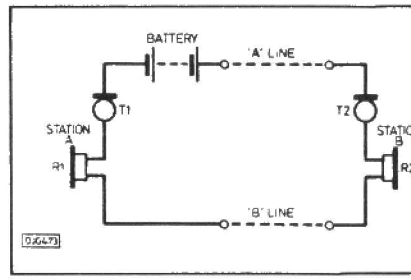
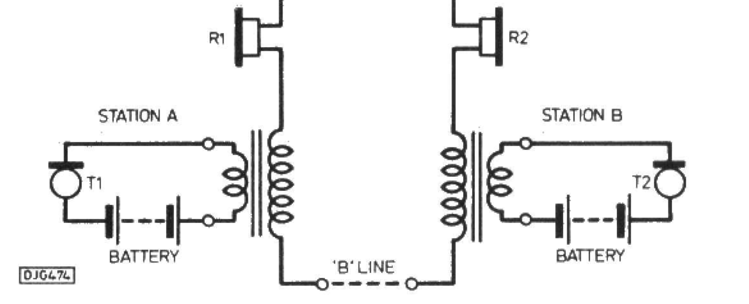


Fig. 1. *First telephone system*

Although it would clearly have been possible to make a working loop with two receivers and two carbon transmitters all in series with a power source, and this was in fact the basis of the first system, (Fig. 1), Edison soon developed a rudimentary impedance matching and isolating circuit using an induction coil. This was a simple transformer with a core of straight iron wires and which was included in the circuit in order to enable the transmitter to be powered by means of a small local battery; a design which produced a high signal strength on the line with a minimum of power, as there was very little resistance in the transmitter circuit in series with the microphone. Fig. 2 shows the method adopted. In addition, the receiver R is isolated from the path of the DC, a procedure which avoided polarisation and allowed improvements to be made in the design of the receiver.

In later systems, local battery operation was replaced by central battery operation. The arrangement in the subcriber's telephone became that shown in Fig 3.

Fig. 2. *Arrangement for local battery operation*



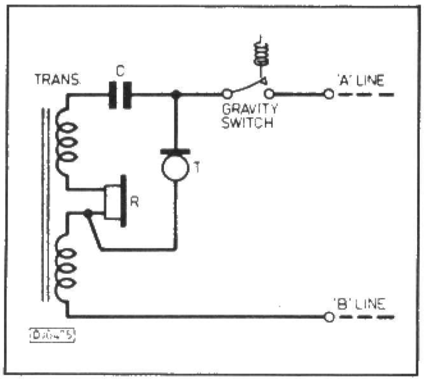


Fig. 3. *Skeleton circuit of central battery telephone*

With this simple arrangement, as also in the arrangements in Figs. 1 and 2, both receivers respond to the same signal equally. This has the unfortunate effect of causing the speaker to speak more quietly than he otherwise would, due to the level at which he hears his own speech, thus severely reducing available signal levels.

The problem was overcome much later by the use of a third winding on the transformer (the Anti Sidetone Induction Coil or ASTIC). The circuit diagram in fig. 4, taken from the familiar 706 telephone shows how this is done. The ASTIC and its associated R/C network causes an antiphase replica of the locally generated speech to be mixed with the signal from the line as it reaches the receiver (earpiece). This action reduces to a very low level the signal due to the user's own speech as reproduced at the local receiver, while placing the full signal from the transmitter on the line pair. The introduction of the ASTIC in the early part of this century was an important one as it allowed the greater signal strengths required by the more complex system that was beginning to develop.

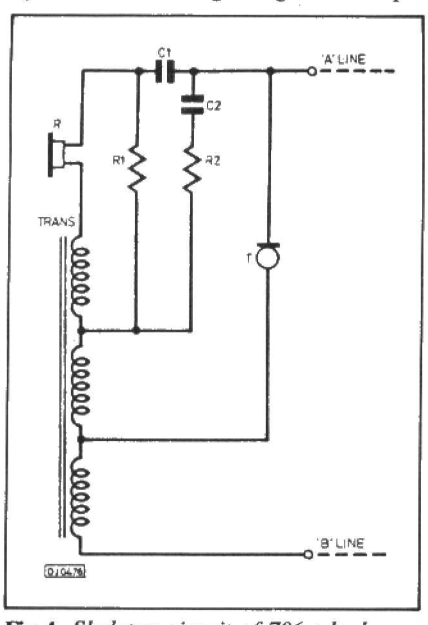


Fig 4. *Skeleton circuit of 706 telephone in speaking condition*

INDUCTION

In 1882, the telephone was much more than just the scientific toy that it had been up till that time. Chambers' Encyclopaedia of that year was able to say: "While the telephone is already very largely used in America for domestic and business communication, it has been less successful in Britain, the busier lines increasing the difficulties arising from induction."

exchange were becoming common, and means of signalling were being adopted which lead directly to today's practice. I do not propose to cover in detail the development of the signalling systems used – they were many and various. To quote one example though, systems had been adopted in the early days which used an AC bell. These were operated by a small hand-wound permanent magnet alternator (magneto).

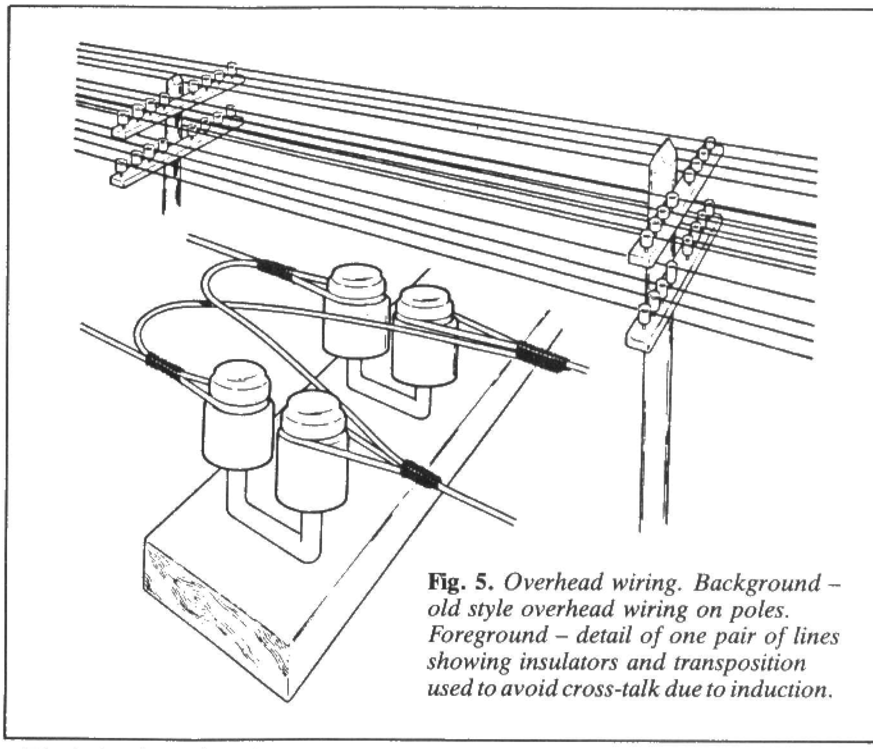


Fig. 5. *Overhead wiring. Background – old style overhead wiring on poles. Foreground – detail of one pair of lines showing insulators and transposition used to avoid cross-talk due to induction.*

The induction referred to was induced 'crosstalk' between adjacent lines, and a great deal of development work was needed before a satisfactory solution was presented. The solution involved balancing the capacitative elements of each line using external capacitors, and also a system of crossing overhead lines (at the support poles), each line-pair crossing with a different frequency and at different poles, (Fig. 5), at fairly frequent intervals, so that lines no longer ran in parallel loops for long distances. The later multipath cables developed for underground use were constructed of many separate twisted pairs of conductors, which achieved the same object.

By this time groups of telephones connected by means of a telephone

To signal the exchange operator, the calling subscriber would operate his magneto. This would activate an indicator at the exchange, there being one for each subscriber. The operator would take the call and ask which number was required. He or she would then signal the called subscriber with the magneto at the exchange, and when answered would establish the call by connecting the two subscriber's lines together with a lead terminated at each end by a jack plug. This was made possible by the fact that all the lines from subscriber telephones terminated at the exchange in jack-sockets, these being manufactured in modular strips as shown in Fig. 6.

To terminate the call, each of the subscribers were required to operate

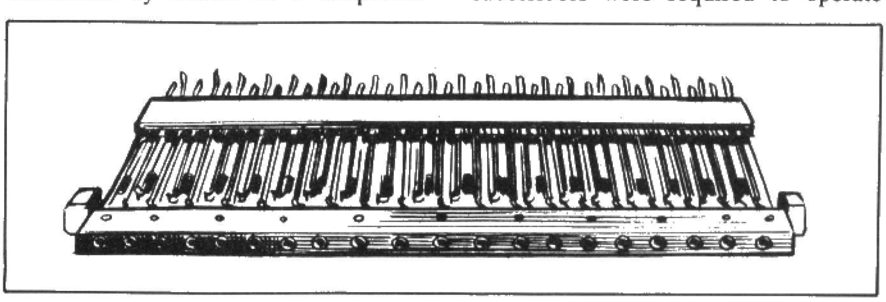


Fig. 6. *Jack socket strip*

their magneto – a process called "ringing off" (ever wondered where our language got the term from?). It was soon discovered that although subscribers would go to any lengths to establish the call, once the call was completed the process of "ringing off" was frequently forgotten. As this engaged some of the exchange equipment needlessly a better method had to be found. It was evident that the only action which could be relied upon at the completion of a call was the replacement of the receiver part of the telephone apparatus upon (quite literally in those days) its "hook". This, then was to be the signal.

D C SIGNALLING

As we have seen above, an AC signal was being used for ringing, as is still the case today. This fact facilitated the introduction of the so called central battery signalling system. (C.B.S. operation).

In place of locally fitted magnetos, the making of a DC circuit by picking up the receiver was used. With the receiver of a telephone on its hook, flow of DC was prevented by placing a 2μF capacitor

AUTOMATIC DIALLING

By 1879, patents were already being granted for the first system of automatic telephone exchange, and a few years later a patent was granted to Almon B. Strowger for the famous Strowger exchange; The system only now being superseded. The first automatic telephone exchange to be installed in this country was commissioned in 1912 at Epsom, and from then until the 1960s Strowger exchanges were gradually introduced to take the place of manually operated ones.

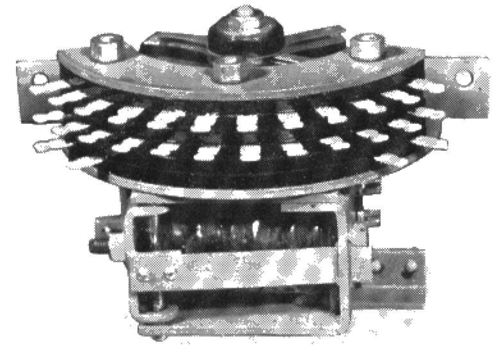
The Strowger system was known as the 'step–by–step' system, and used automatic switches which responded to a series of pulses (impulses). This gave rise to the third and final part of the specification still used on the Telecom system today – that of pulsed dialling. The passing of DC through the local telephone signalled the automatic exchange that a call would be made. The familiar "dial tone" was then placed on the line by the exchange equipment signalling that the equipment was ready to receive a dialled number. Use of the dial then caused the DC flowing in the

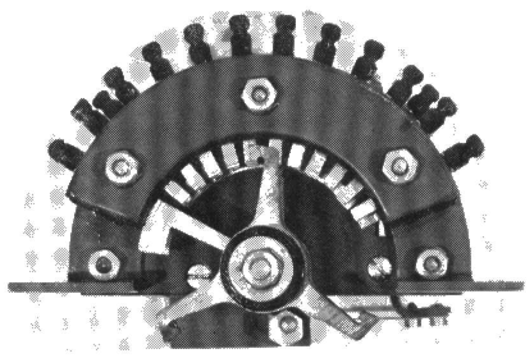
is operated, some 30 to 50 mA of DC flows which signals the exchange. Thus were established one hundred years ago the specifications for currents, voltages, signalling and dialling pulses that we use today.

THE STROWGER EXCHANGE

The idea of a method whereby any one of a group of telephones could be connected automatically to any other was one which fascinated Almon B. Strowger. Commencing with the concept of ten telephones, he thought through the concept of a cumbersome number of relays, to a simple electromagnetically actuated ten position selector switch. The 'minor' switch, or uniselector as it was later called, was the basis of the first public exchange (photographs 1 and 2).

This required a five–way cable to each telephone; one pair of wires to operate the driving magnet – a solenoid which stepped the switch up one position for each impulse; a pair of wires to operate the release magnet – a second solenoid which returned the selector to the rest position. The fifth wire was the 'speech'





The photographs of the Uniselectors, and the drawing of the jack strip were kindly made available by Service Trading Company of 57 Bridgeman Road, London W4 5BB.

Uniselector swith. Left, rear view. Right, top view.

in series with the bell. Ringing current saw this as a series impedance, and adequate current to operate the bell flowed. A switch was fitted to the receiver hook (Fig. 3) which allowed speech current to flow through the transmitter T, and the primary winding of the transformer.

Some 30mA of DC would flow through the local instrument, the line, and the exchange. This was used to operate a relay at the exchange, with a lamp or other indicator showing to the manual operator that a subscriber was "on the line". Although for a time, C.B.S. was used together with a locally fitted battery, this system was rapidly overtaken by the central battery system (C.B. operation) in which all the power, both for speech and for signalling, was fed from the exchange. The same signalling method was later used to establish entry to an automatic exchange system.

line to be interrupted 10 times per second according to the number dialled. That is to say one interrupt pulse to dial one, two pulses for two, up to ten pulses for zero.

This system is known as the loop–disconnect system and remains the main system accessible to the subscriber today. The specification, then and now, was that the mark–space ratio should be 1:2, rounded to 33ms make and 67ms break. The maximum permitted variation of speed was 9 to 11 pulses per second.

Prior to the large–scale introduction of automatic exchanges "central battery" working had become the norm, so no power needed to be provided at the subscriber's instrument. The end result is a line–pair reaching your house which carries about 50V DC when no connection is being made. When the phone is ringing, about 75VAC at 17Hz is superimposed, and when your phone

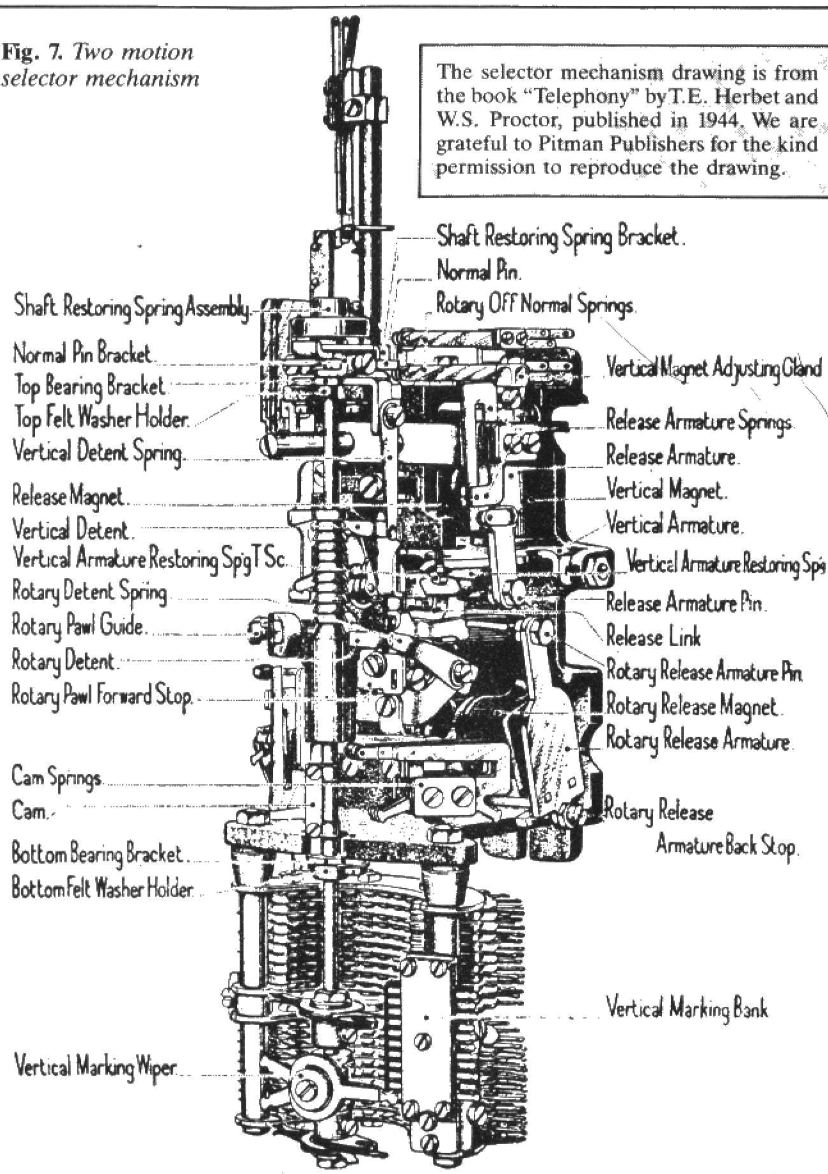
wire, carrying all communications, and using the earth as a return path.

An idea of the sheer quantity of equipment required may be seen by thinking of a single telephone line connected to a single uniselector. This will allow dialling of one digit to select one of ten paths. For a second digit, each of those paths will have to be connected to a further uniselector – eleven uniselectors for a single speech path. In its crude form then, a single one hundred line exchange could comprise as many as one hundred times eleven uniselectors!

Mindful of the complexity of a system built up with uniselectors, Strowger envisaged a development in which one hundred connections might be selected using a single switch. The two–motion selector, or multiselector as it came to be known, was modelled by Strowger using a circular cardboard box (a collar box for those readers who are old

Fig. 7. *Two motion selector mechanism*

The selector mechanism drawing is from the book "Telephony" by T.E. Herbet and W.S. Proctor, published in 1944. We are grateful to Pitman Publishers for the kind permission to reproduce the drawing.



enough to recognise the term!) He cut the box in half lengthwise, and inserted one hundred common pins through the cardboard in a pattern of ten ranks of ten rows. He was then able to show that a centrally fitted contact could reach any single pin by first rising through the required number of levels and then rotating through to the final position.

Having established the principle, he built and tested the prototype multiselector. (Fig. 7 shows the principle). It has contacts rather like those on the uniselector, but stacked in ten banks or levels, and with only one set of wipers for the whole assembly. The operating mechanism is designed to accept two digits consecutively – the first digit selecting the level, and the second causing the rotary motion, just as in the uniselector. The two–motion selector could then respond to two consecutive digits, allowing one hundred numbers to be selected, 00,01,02, through to 99.

Later, more complex exchanges would use serial combinations of two–motion selectors to respond to multiples of two digits, and so build up the Strowger exchanges still in use today. This of course presents a much simplified picture.

Imagine a system to cater for one thousand lines, and capable of connecting any one to any other. Firstly, the equipment has to respond to a calling signal (initiated by lifting a receiver), it then has to seek out or "hunt", for a free selector – think about it! All one thousand lines will never be in use at the same time, so the number of selectors is calculated according to a probability formula. (The mathematics, as in all probability work, is fascinating but very complex, and was developed originally by a Danish mathematician named Erlang who gave his name to the unit used to define call–density).

A preselector in connection with each line operates to engage selection equipment when required. When a selector is connected, dial tone is placed on the line. Dial pulses then operate selectors until at the last digit, final selection is made. Having obtained the right line to be called, the equipment then has to test that this line is free, responding to the caller with an engaged tone if not. Assuming that the line to be called is free and the connection can be attempted, the ringing signal has to be placed on the line to be called, together with the ringing tone on the calling line (they are not the same thing). The equipment then has to test for an answer, only making the final connection when this occurs. And that's just one thousand lines; just three digits' worth! How long is your telephone number; not including the trunk dialling code? Even so, the principle remains broadly the same – only the quantity of equipment is multiplied. PE

In Part Two next month Barry Drake picks up the story again, from the days of Crossbar

HOW TO USE THESE TRACKS

FIRST MAKE TRANSPARENT COPY

(We regret that we cannot supply transparent copies of PCB track layouts.)

ISODRAFT METHOD

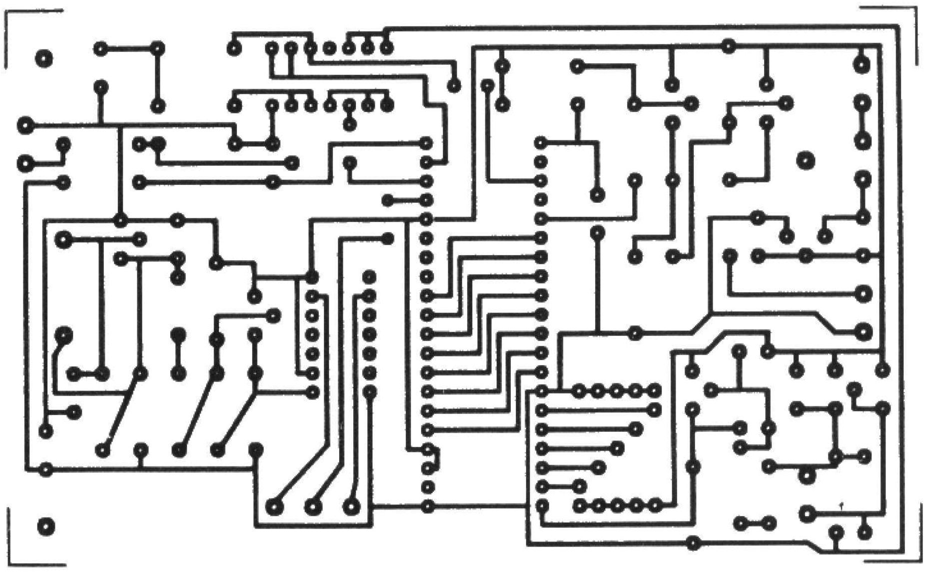
Have a normal photocopy made, ensuring good dense black image. Spray ISOdraft Transparentiser onto copy in accordance with supplied instructions. **ISOdraft** is available from **Cannon & Wrin,** 68 High Street, Chislehurst, Kent. Tel: 01-476 0935.

PAINSTAKING METHODS

Draw image by hand onto clear film or drafting film using dense black ink. Draw direct onto copper surface of PCB fibreglass, using etch-resist inking pen. Use etch resist PCB tracks and pads, taping direct to copper surface, or onto drafting film.

NEXT PRINT ONTO PCB

Place positive transparency onto photosensitised copper clad fibre glass, cover with glass to ensure full contact. Expose to Ultraviolet light for several minutes (experiment to find correct time – depends on UV intensity).



PE 160

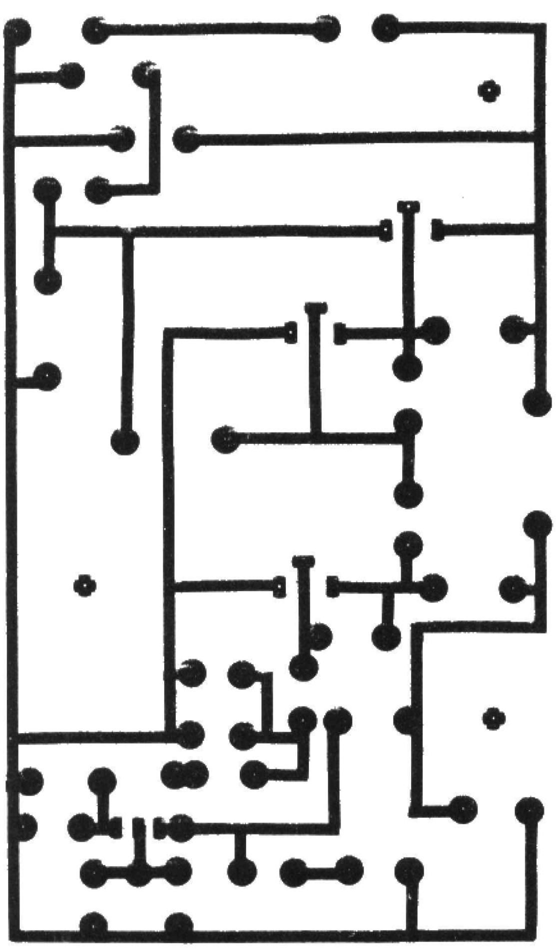
Develop PCB in Sodium Hydroxide (available from chemists) until clean track image is seen, wash in warm running water. Etch in hot Ferric Chloride, frequently withdrawing PCB to allow exposure to air. Wash PCB in running water, dry, and drill holes, normally using a 1mm drill bit.

(PCB materials and chemicals are available from several sources – study advertisements.)

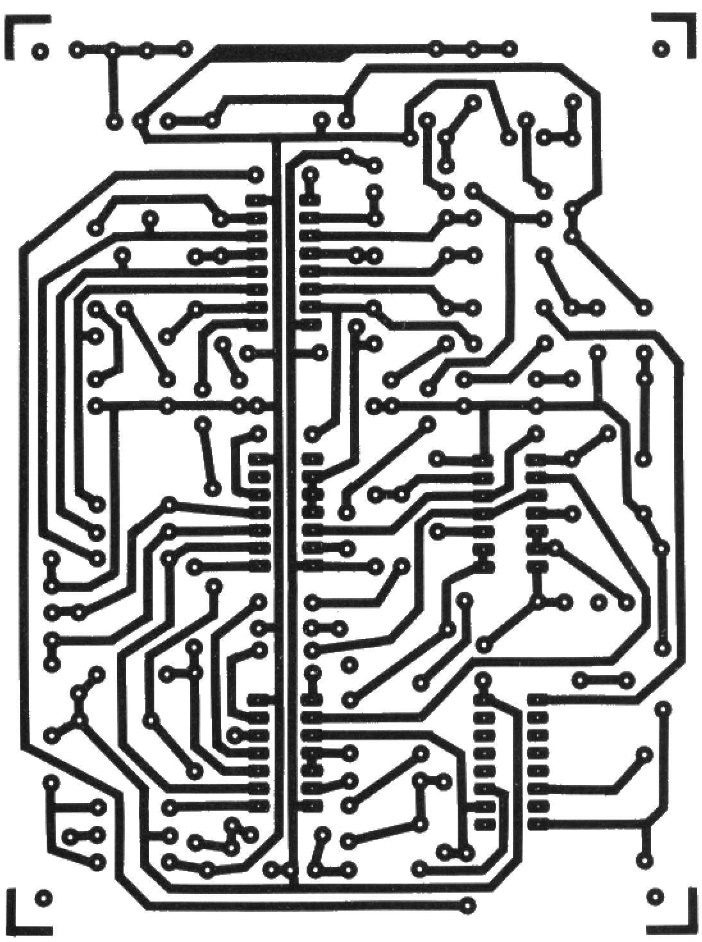
*** CAUTION – ENSURE THAT UV LIGHT DOES NOT SHINE INTO YOUR EYES. PROTECT HANDS WITH RUBBER GLOVES WHEN USING CHEMICALS.**

ALTERNATIVE METHOD

Buy your PCB ready made through the PE PCB SERVICE, most are usually available – see page 56. PE



PE 161



MULTIZONE BURGLAR ALARM

TEACHER RADIO

BY TIM PIKE

The fourth in a series of articles aimed at giving GCSE students of Electronics ideas and guidance with practical projects

A simple radio requires only some lengths of wire, a pair of headphones, a loo roll to wind the coil on, and two tall trees. Teacher Radio *is a little more sophisticated.*

To the young enthusiast, and for that matter the not so young, the ability to create a piece of circuitry which will detect radio signals and reproduce the sounds which are being transmitted, perhaps hundreds of miles away, must rank as one of the most exciting events in his or her experience.

IN THE BEGINNING

I well remember building my first crystal set with my father's patient help. After some hours of work, which included winding the coil and making a wooden box for the delicate components to reside in, the thrill of connecting a pair of high impedance headphones and turning the dial was unforgettable. I think it received just two stations and the interference was horrendous but nevertheless it worked (and it didn't even need a battery!)

I relived this experience when playing around with a now famous circuit fabrication system some thirteen years ago.

As I built a simple circuit for a radio with single transistor amplification, the laboratory technicians, in whose preparation room I was working, were amazed to hear a strong signal emerge which sounded very much like Radio 1 – and all this in only ten minutes or so! Such is the fascination of radio circuits.

It is not my purpose here to offer the expert any new insight into sophisticated radio circuits. Rather, I intend to start from the same beginnings as I, myself, experienced some twenty-five years ago, with the principle of the crystal set. From here, I will develop some simple solutions to the most obvious problems associated with such a crude receiver. Along the way I will try to give as much background as possible to help the beginner to grapple with the whole notion of radio signals and how they are transmitted, propagated and received.

THE CRYSTAL SET

Without worrying too much for the moment about the nature of radio signals, if we accept that they exist in

space all around us, all the time, then it is clear that we need to be able to capture some of their energy. An aerial, which may be no more than a long straight piece of wire suspended horizontally between two trees, and connected into the receiver will do to start with.

Having captured some of the energy, we now need to select a particular 'channel', station or transmitter and to reject all others. This is the function of the tuning circuit.

We must now "demodulate" or "detect" the audio signal, by removing it from the radio signal which has carried it through space. All that now remains is to convert the electrical signal into an audio signal using a suitable transducer. This will have to be a device which requires very low current and voltage inputs since the basic circuit has no external power supply. A pair of high impedance headphones is the obvious choice. So we have the minimum four essential elements for our simple receiver (Fig.1.) We must now fill in a little more detail.

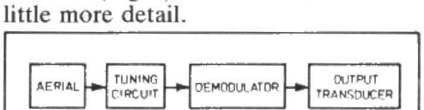


Fig. 1. *Minimum features of a radio receiver*

THE TUNING CIRCUIT

The basic tuning circuit consists of a capacitor and an inductor (coil). (Fig.2.) One of these two components must be variable in order to change the station being selected. Except in very 'noisy' environments such as motor cars, it is most convenient to have a fixed inductor and a variable capacitor.

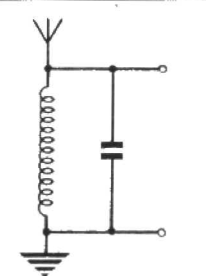


Fig. 2. *Basic tuned circuit*

The parallel combination of these two components provides a circuit whose frequency response 'peaks' at one particular frequency. The capacitor has reactance which decreases as frequency increases.

$$X_C = 1/2\,\pi\,fC$$

The inductor has a reactance which increases as frequency increases.

$$X_L = 2\,\pi\,fL$$

At one particular frequency (the "resonant" frequency) the two reactances will be equal. Students of GCSE level do not need to concern themselves with the actual phase relationships nor with the complex mathematics required to express them but it is important to understand that the resonant frequency is the one frequency at which the two reactances are equal (and in fact, opposite). This gives rise to the special effects which are observed at this frequency.

To complete the simple mathematical analysis we form an equation by putting X_L and X_C equal to each other.

If $X_L = X_C$ then $1/2\,\pi\,fC = 2\,\pi\,fL$

By re-expressing this relationship to make 'f' the subject of the equation,

$$f = 1/2\pi\sqrt{LC}$$

So, for a given capacitor value (in Farads) and a given inductor value (in Henrys) we can calculate the expected resonant frequency.

There will be many combinations of capacitor and inductor values that give the same resonant frequency (theoretically an infinite number of combinations). In practice we are restricted to a smaller range of values of the two components because they are only available in certain 'preferred' values.

Table 1 gives some examples of values and resonant frequencies.

TABLE 1

CAPACITOR	INDUCTOR	RESONANT FREQUENCY
10pF	10μH	15.9MHz
47pF	50μH	303MHz
100pF	500μH	711kHz
500pF	1 mH	225kHz
1nF	10μH	1.59kHz
10nF	100μH	159kHz
330pF	10 mH	87.6kHz
220pF	100μH	1.07MHz
100pF	1μH	15.9MHz

It can be seen that it requires a hundred-fold increase in the values of the inductor and capacitor, when multiplied together, to bring about a ten-fold decrease in the resonant frequency. This will turn out to be very useful because it means that very fine control of the resonant frequency can be obtained even with a fairly coarse variable component.

DEMODULATION

Moving onto the demodulator or detector stage, the simplest device that will perform this function is a single diode. The radio frequency (R.F.) signal consists of a high frequency sine wave which has been modulated by the signal that we are trying to detect. If you are uncertain about the whole idea of modulation and demodulation then don't give up now. Later on we will look at this in a little more detail.

Fig.3 shows symbolically the original carrier wave, the original signal (audio) and the combined, modulated signal. The diode is used to remove one half of the modulated wave. (Fig.4.)

We must now filter out the high frequency components which remain by using a suitable capacitor. The headphones connected in parallel with this capacitor must have a higher impedance than the capacitor at radio frequencies but a much lower one at audio frequencies. (Fig.5.)

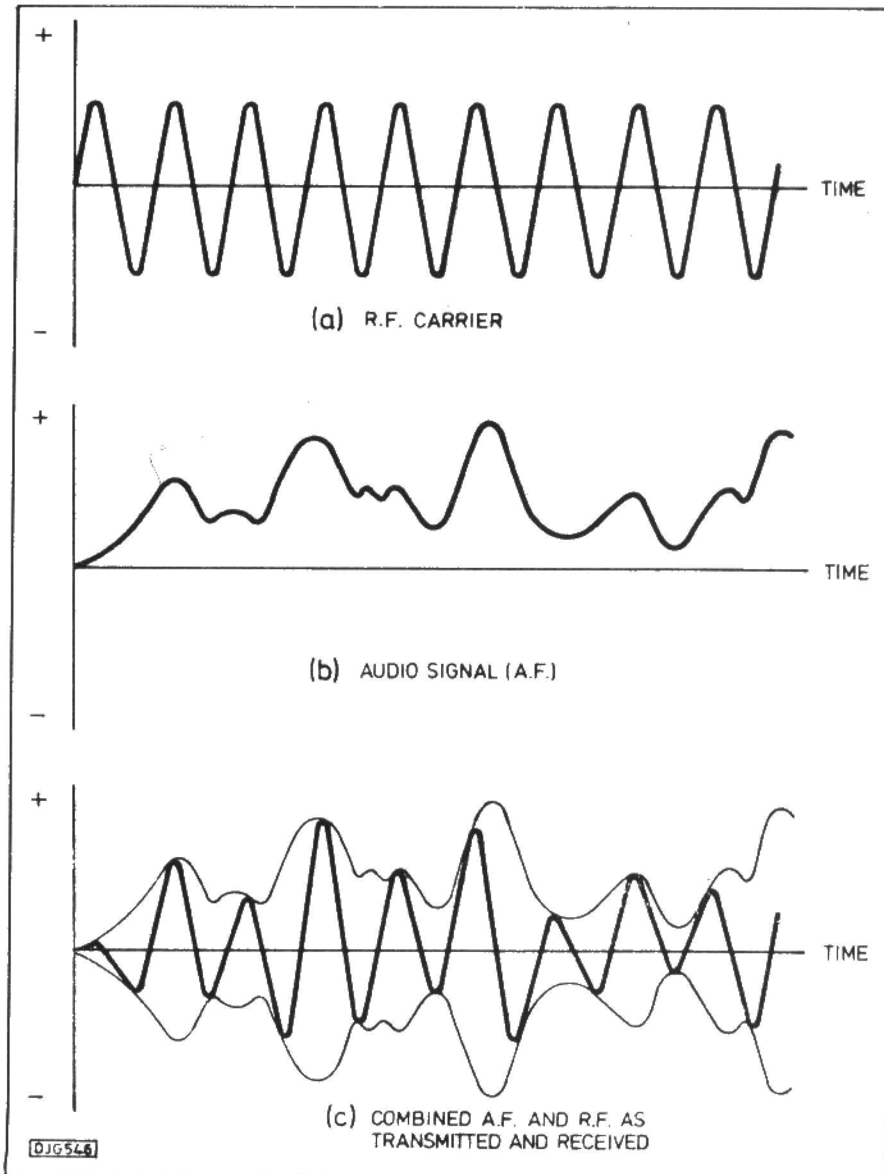


Fig. 3. *The amplitude modulation process*

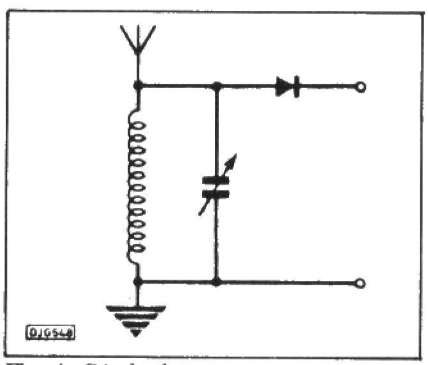


Fig. 4. *Diode detector*

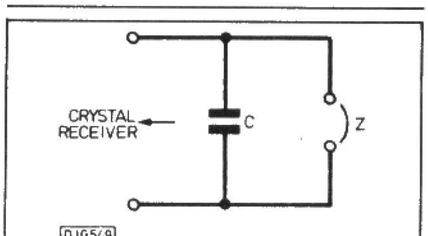


Fig. 5. *Simple capacitor filter to by-pass R.F. from headphones*

Suppose the radio frequency is 1MHz and the highest audio frequency is 10kHz.

At f = 1MHz (10^6 Hz),

$$Z > \frac{1}{2\pi fC}$$

At f = 10kHz (10^4 Hz),

$$Z < \frac{1}{2\pi fC}$$

So, to satisfy both of these requirements, the headphone impedance will need to be equal to the reactance of the capacitor at, say, 100kHz. If the headphones have an impedance of 2000 ohms, then

$$2000 = \frac{1}{2\pi \times 10^5 \times C}$$

which gives

$$C = \frac{1}{2\pi \times 10^5 \times 2000} = 800\text{pF}$$

If we choose our tuning circuit components to be an inductor of 50μH and a variable capacitor with a maximum setting of 500pF then we can tune to stations in the frequency range 1MHz to 7MHz (approx). Many readers will be more familiar with the corresponding wavelengths of these broadcasts.

In order to convert from frequency to wavelength, we use the well known relationship $v = f \times \lambda$ where v stands for velocity (in this case the velocity of radio waves which equals the velocity of light), f is the frequency and λ the wavelength. Rearranging this formula gives $\lambda = v/f$.

The velocity of light is approximately equal to 3×10^8 m/s. So a station whose carrier frequency is 1MHz has a wavelength of 300m. One whose carrier frequency is 7MHz has a wavelength of 43m. These wavelengths represent stations in the lower half of the medium wave band and somewhat below this band.

The basic crystal set circuit then is given in Fig.6. Notice the earth connection. This must be a real earth which might be obtained either from the mains earth connection for your house or by connecting a wire to a metal stake and driving this into the ground. The circuit will not function properly unless the earth connection is good.

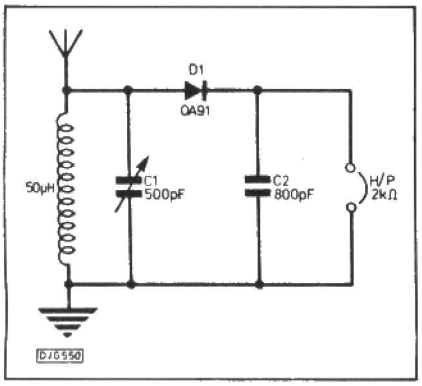


Fig. 6. *Basic crystal receiver*

SENSITIVITY AND SELECTIVITY

If you build this circuit you will find that it is very limited in operation and exhibits two main problems which are found in all simple and therefore inexpensive radio circuits.

The first problem is one of poor sensitivity. Sensitivity is a measure of the ability of the reciever to detect the weaker signals which come within its tuning range. With a good aerial and when it is reasonably close to the transmitter, the receiver will work fairly well. 50 to 60 miles is usually considered to be the maximum range for such a receiver.

The second problem is that the crystal set also has poor selectivity. Selectivity is the ability of the receiver to receive just one of two or more closely spaced transmissions. Good selectivity requires that the tuning circuitry has a very sharp response. The ideal response would be one centred exactly on the carrier frequency and with a frequency spectrum extending by the required signal range on either side of the carrier frequency. Suppose the audio signal includes frequency components up to 10kHz and the carrier in use is 1MHz. The ideal tuning circuit will then have a frequency response which looks like that shown in Fig.7a.

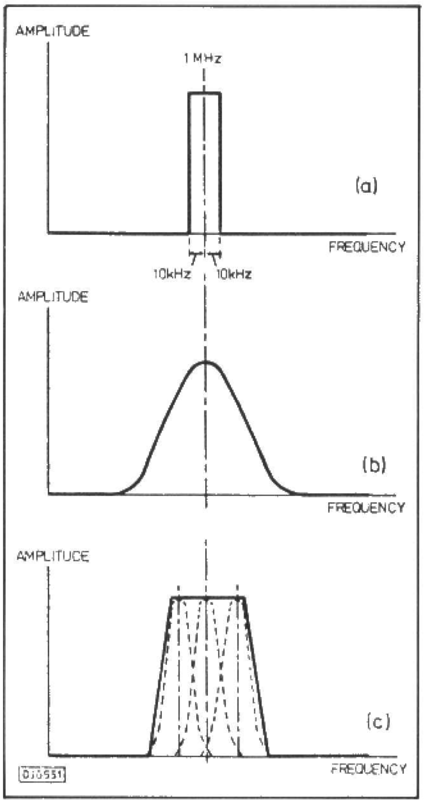


Fig. 7. *Tuning responses. (a) Ideal. (b) Typical. (c) Improved.*

In practice, even the most sophisticated tuning circuits cannot produce such an ideal response. All real response curves have the familiar 'bell' shape of Fig.7b. By combining two, three or more of these, however, a response not unlike that of the ideal can be obtained. (Fig.7c).

This is the principle employed in more complex radio tuning circuits where a 'ganged' capacitor controls two or three resonant circuits at once. These circuits are beyond the scope of an article aimed at GCSE pupils.

MATCHING

The first improvement worth considering is to replace the simple coil with either a double-wound coil or a radio frequency transformer. The number of turns on the coil determines its inductance which in turn determines the frequency range that the set will receive. The diode has a low impedance and is therefore better matched to only a few turns of wire, but this would not suit the tuning circuit except for short wave reception.

We can satisfy both requirements if the primary winding forms the tuned

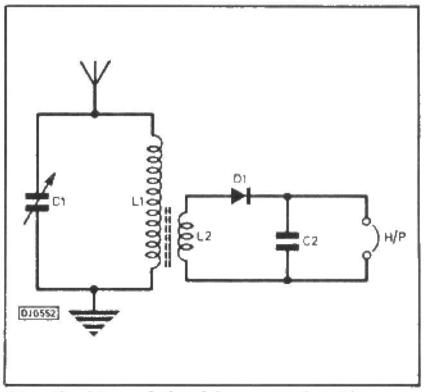


Fig. 8. *Use of double-wound coil*

circuit and the secondary winding couples the signal into the diode. The circuit of Fig.8 results.

You can learn a great deal about the effect of changing the number of turns of wire both for L1 and L2 if you wind your own coils. You will need a piece of ferrite rod and some enamelled copper wire. The gauge of the wire is also important – try to obtain 24 s.w.g. or close to it.

If you use paper sleeves before you start to wind your coils, you can easily remove them and try other values without having to unwind the previous coils. (Fig.9).

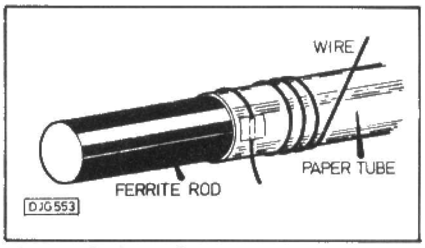


Fig. 9. *Coil winding*

A few open turns will tune to short wave stations. More turns will tune to the trawler band (shipping) and the amateur bands. Somewhere between 50 and 100 turns should tune to the medium wave band and 150 to 200 turns will bring you into the long wave band.

The use of the double coil should give some improvement in selectivity but the circuit is still self powered and capable of driving only a pair of high impedance headphones.

AMPLIFICATION

The next level of improvement comes by adding a transistor.

If we continue to use the crystal receiver circuit of Fig.8 but add to it a simple transistor amplifier to give more volume and the possiblity of driving a loudspeaker instead of the headphones, then the circuit of Fig.10 results.

Capacitor C3 couples the audio signal into the amplifier but prevents d.c. from the amplifier flowing back into the receiver circuit. VR1 gives some control over the amount of signal presented to the amplifier. It will function as a crude volume control. R1 will bias the transistor into conduction. Any general

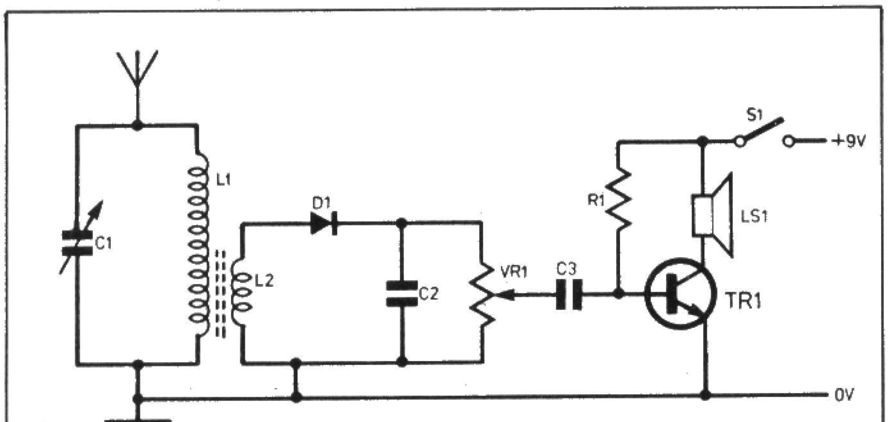


Fig. 10. *Crystal receiver with single transistor amplifier*

audio amplifier transistor will give good results providing the input signal is adequate. The loudspeaker will need to be of a fairly high impedance (64Ω or 80Ω).

A COMMON MYTH

It is often thought that the addition of some amplification turns a poor receiver into a better one. This is quite wrong. The transistor has done nothing to improve either the sensitivity or the selectivity of the circuit. It has simply given more volume and the option of driving a loudspeaker. The basic qualities of the receiver itself are unchanged. It will not suddenly receive weak stations and it will not tune any better to one particular station. In order to help to bring about these improvements we need to amplifiy the signal before it is detected. This will require a radio frequency (RF) amplifier circuit rather than an audio frequency (AF) amplifier as discussed above.

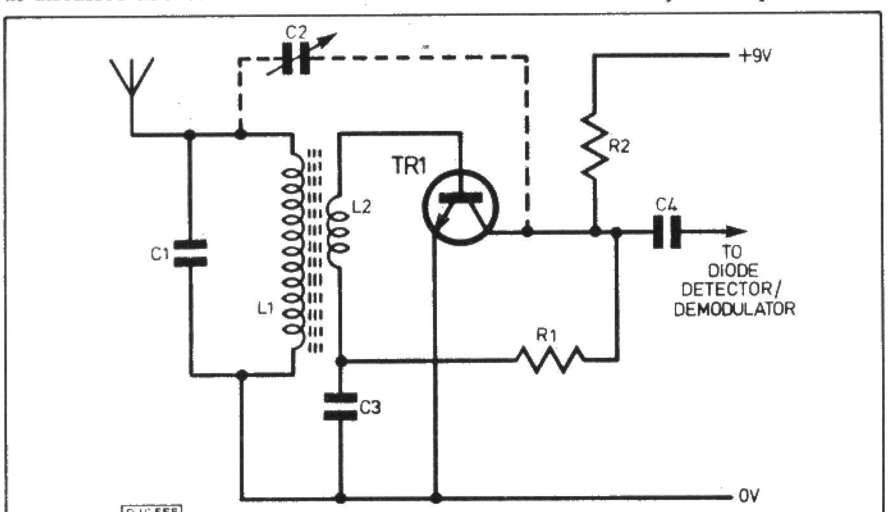


Fig. 11. *Typical R.F. transistor amplifier*

SIMPLE RF AMPLIFIER

Fig.11 shows a typical example of an RF transistor amplifier. This will increase the range and sensitivity of the set but since it still only has one tuned circuit, the selectivity will not be markedly different. If an element of positive feedback is introduced (by adding C2) then this will offer some improvement to selectivity as well, but only marginally. There is no alternative to a more sophisticated tuning circuit if greatly improved selectivity is required. Such circuits are beyond our scope.

We now have an overall design which consists of the elements shown in the block diagram of Fig.12. This is as far as we need to go in developing the theory, but let's for a minute return to basics to fill in some of the background ideas about radio waves before we come to the final circuit suggestions.

RADIO WAVES, PROPAGATION AND RECEPTION

Experience tells us that to attempt to communicate sound energy directly over distances of more than a few hundreds of metres is not only very difficult but very annoying to others who do not wish to receive the transmission! Radio waves which form a very small part of the electromagnetic spectrum are conveniently used as a "carrier". Not only does this give greatly improved range but it also has several other advantages. Firstly, radio waves travel at the speed of light and therefore transmission is very fast. Secondly, the frequencies involved are well outside our audio range and we are therefore oblivious to all the information which is flying around the earth day and night.

The carrier principle can be used in many different ways. The simplest way involves just turning the carrier on and off such as in Morse Code. This is of course limited and relatively slow if complex information is to be transmitted. Modulation of the carrier, which means changing it in some way, offers a much more flexible means of conveying information. GCSE students need to be aware of both Amplitude Modulation (AM) and Frequency Modulation (FM) but more detail is usually required for AM. All the simple radio recievers contained in this article are only suitable for AM reception, so let's look to see how this method of modulation works.

A carrier wave of fixed frequency (e.g. 200kHz for BBC Radio 4) is modulated by varying its amplitude. The rate at which the carrier strength varies is determined by the frequencies of the speech or music. The amount the carrier strength varies is determined by the loudness of the audio signal. Silence should correspond to a constant carrier amplitude (Fig.13a). A loud audio signal will be heavily modulated and may look like Fig.13b. All the radio circuits developed in this article have to undo this process and extract the original audio signal from the carrier. How then are radio signals propagated through space?

Essentially there are two possibilities. A wave of radio energy can either travel to us directly, following a line of sight or it can be directed upwards until it reaches the higher ionized layers in the Earth's atmosphere, which act like mirrors and reflect it back. It is possible to send a radio signal all round the world by reflection from the ionosphere. This explains how the very sophisticated radio transmitters and receivers used by amateur radio enthusiasts enable them to talk to each other from opposite sides of the world.

FREQUENCY MODULATION

Although GCSE work usually includes very little detail of FM (Frequency Modulation) it is worthy of

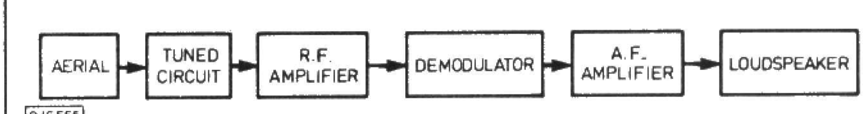


Fig. 12. *Features of an improved radio receiver*

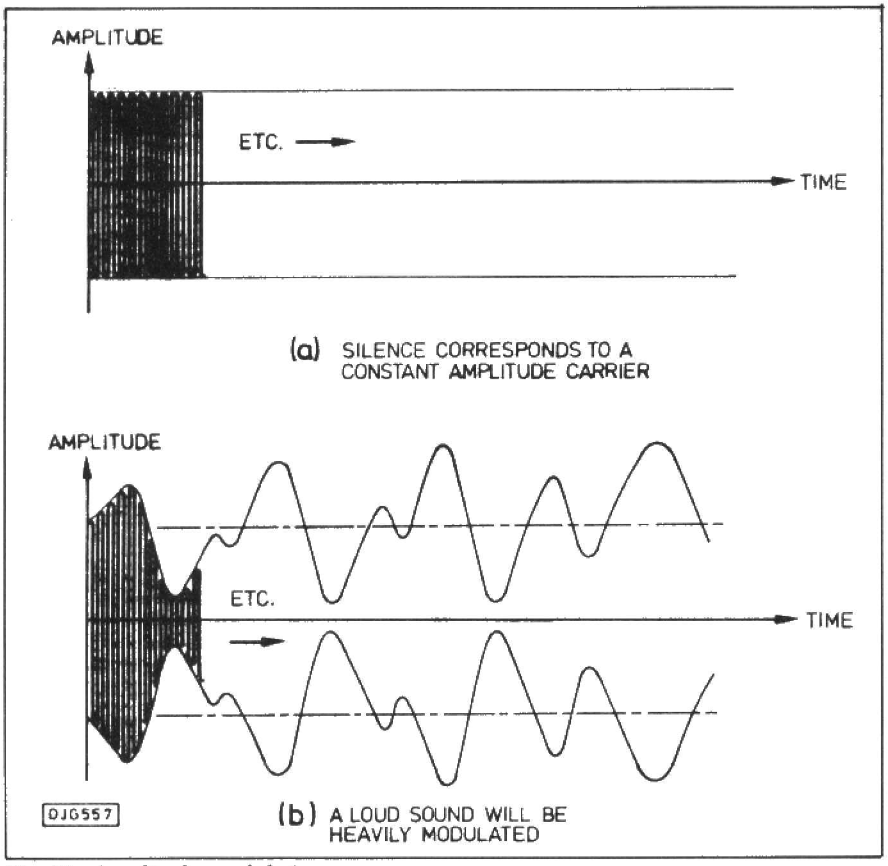


Fig. 13. *Amplitude modulation*

a brief mention if only because it is so superior to AM.

One of the main advantages of an AM transmission (and reception) system is that it is essentially simple both in technology and in implementation. These factors make the system cheap and thus available to all.

In recent years, FM systems have become more popular and nowadays a great deal of serious listening to the radio is done on the FM band. The disadvantages of AM systems are the advantages of FM systems. Most of these are concerned with the quality of reception. The very earliest experiments in radio transmitters were conducted using spark transmitters. In fact all sparks propagate in space on a wide range of frequencies. All AM systems are therefore subject to impulsive noise. You will have noticed what happens to your radio reception when a motor vehicle is driven down your road if it is not fitted with proper suppression on the high voltage parts of the electrical system. Lightning has a similar effect on radio and TV reception. Impulsive noise is generated by electric motors, arcing switch contacts and so on. It can be so serious in its effects that it makes it almost impossible to concentrate on the broadcast signal. The second disadvantage of AM is again concerned with quality.

Referring back to Fig.7, the ideal audio response of a radio receiver would cover all frequencies in the audio range (20Hz-20kHz). Since the modulation process requires that this frequency range appears on either side of the carrier (this is what is meant by the two "sidebands") the channel width would have to be 40kHz.

Broadcasting space is very limited on the AM system because there are so many transmissions and each requires its own 'channel'. In practice it is not possible to separate one channel from the next by 40kHz. In fact, of course, they are sometimes hardly separated at all which is why great demands are put on the receiver if it is to detect one and not the next. The reduced space available means that a reduced 'bandwidth' is allowed for each channel and this effectively reduces the quality of sound by cutting out all the higher frequency components.

FM was developed in an attempt to overcome some of these problems. The transmitter again couples a sinewave to an aerial but this time it is the frequency of the sinewave which varies in sympathy with the audio signal. The amplitude of the transmission is kept constant. The receiver is designed such that the demodulated output is insensitive to impulsive amplitude changes and therefore insensitive to impulsive noise.

Fig. 14.
The final design

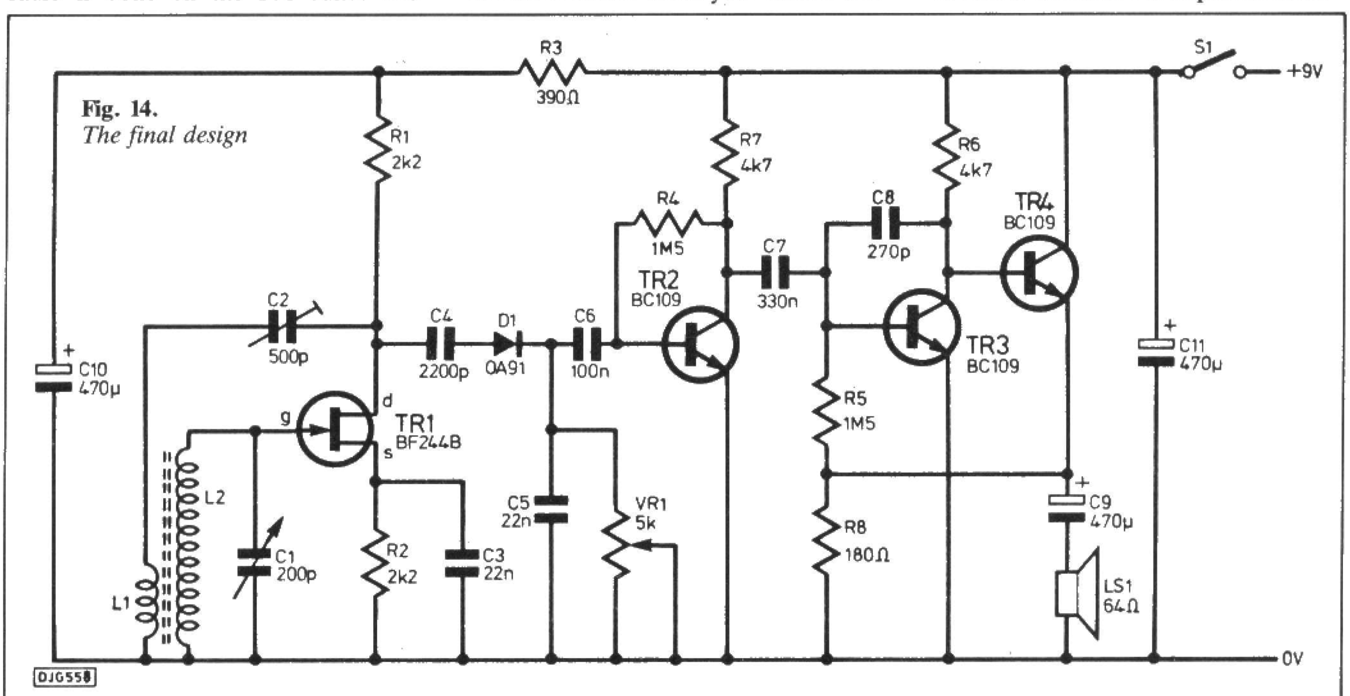
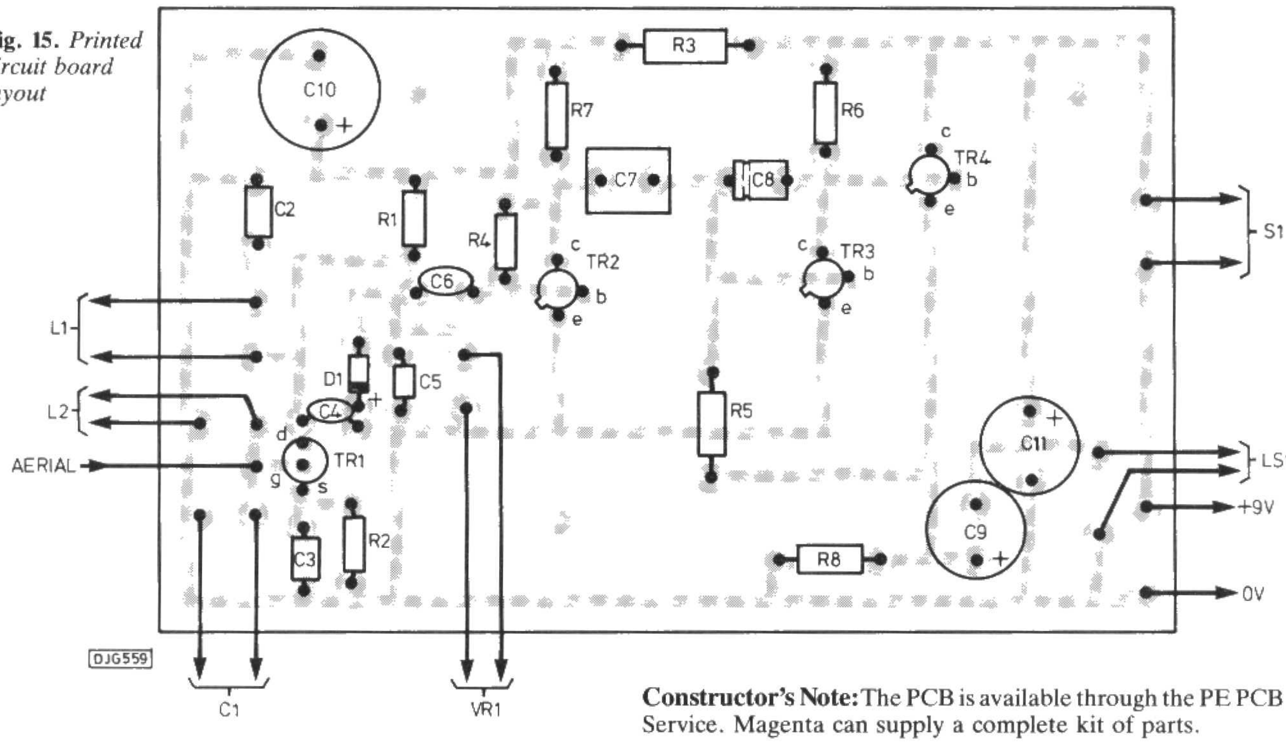


Fig. 15. *Printed circuit board layout*



Constructor's Note: The PCB is available through the PE PCB Service. Magenta can supply a complete kit of parts.

The bandwidth required for an FM transmission is higher still than for the ideal AM transmission. An FM bandwidth of 100kHz is typical. This huge amount of broadcasting space can only be accommodated by working with much higher carrier frequencies where the space available is much more plentiful. FM stations are only found on the VHF band. This band stretches from 87 to 108 MHz.

If each channel requires 100kHz bandwidth then it is possible to accommodate 210 channels without any overlap within this range.

FM sounds so good that you might be wondering why it has not replaced AM entirely. There are some disadvantages. I have already implied that the equipment is much more complex and therefore much more expensive. Coupled with this is the fact that the VHF transmitters have a range of only about 50 miles. More transmitters are therefore required to give national coverage. The result is that we live in a time when both systems are required for different reasons. Whether or not the future lies in FM only is a matter on which a range of opinions could be held. What is certain is that simple designs offered here are well outside of this level of debate.

To return to the constructional project, we can now look at a couple of other practical improvements to the earlier circuits.

FURTHER PRACTICAL IMPROVEMENTS

In developing the final circuit I would like to make just two more improvements. The audio amplifier is very crude with only one transistor. We can do better than this if we use two or three stages of amplification.

The final design is given in Fig.14. Transistors TR2 and TR3 form two stages of audio amplification to give high gain based on common emitter amplifiers. C7 plays an important part in introducing some high frequency negative feedback which preserves the stability of the circuit. In the presence of RF signals, high gain amplifiers often suffer from "RF breakthrough" and consequent instability. C7 should help to prevent this. The final audio stage is based on another BC109 transistor but this time used in the emitter follower mode. This serves to match the fairly high output impedance of TR3 to the fairly low input impedance of the loudspeaker.

L1 and L2 can either be purchased as a ready built ferrite aerial or could be constructed as suggested earlier.

If you are winding you own coils then start by trying 4 turns for L1 and 60 turns for L2 of 24 s.w.g. enamelled copper wire on a ⅜ inch ferrite rod.

If you live in an area of strong reception you may not need an external aerial at all, in which case your radio will be truly portable. I found that some signals could be heard without an external aerial but not at sufficient volume to be acceptable in normal use. A 10 metre length of single core insulated wire suspended well above ground level works very well indeed. The design given includes this facility.

Notice the other special feature of this design. I have chosen to use a field effect transistor (fet) for TR1 rather than a bipolar transistor. The fet has a very high input impedance and therefore draws only a very small current from the input. This is vital in a tuned circuit application because there is so little current available from the radio signal. Transistor TR1 forms the RF amplifier; transistors TR2, TR3 and TR4 form the AF amplifier.

REGENERATION

It is worth pointing out why the output of TR1 (the 'drain' which behaves like the collector of an NPN transistor) is connected back to the coil L1 through C2.

This is an example of positive feedback or "regeneration". The effect is to improve the gain and the sensitivity of the receiver, as well as offering some improvement in selectivity.

The amount of regeneration is controlled by the setting of C2 which is a preset capacitor or "trimmer". Too little feedback will give poor gain and selectivity. Too much feedback will cause the circuit to oscillate.

Capacitor C1 is the tuning capacitor which must therefore be of the variable type to which you can connect a dial and knob. Volume control is provided by VR1 which sets the amount of detected audio signal passed onto the audio amplifier. Unless you have very strong input signal strength you will probably need this control set fairly high.

CONSTRUCTIONAL HINTS

If you hope to use your radio without an external aerial then you must use a plastic container and not a metal one. A metal case would screen the ferrite aerial from the incoming radio waves!

Care is needed with the direction of windings of the two coils L1 and L2. One reason for very poor reception, or

RESISTORS

R1,R2	2k2 (2 off)
R3	390
R4,R5	1M5 (2 off)
R6,R7	4k7 (2 off)
R8	180

All ¼W 5% carbon film

POTENTIOMETER

VR1	5k log.

CAPACITORS

C1	200 pF max. Variable with spindle
C2	500 pF trimmer
C3,C5	22nF plastic film. (2 off)
C4	2200pF
C6	100 nF
C7	330 nF
C8	270 pF ceramic plate
C9,C10, C11	10V. 470μ electrolytic (3 off)

SEMICONDUCTORS

D1	OA91 diode
TR1	BF244B f.e.t.
TR2-TR4	BC109 (3 off)

MISCELLANEOUS

L1/L2	Ferrite rod and enamelled wire (see text)
LS1	Loudspeaker (see text), 64Ω or 80Ω.
S1	SPST toggle switch.

Plastic box, (150 x 90 x 55mm), knobs (2 off), wire, solder, 9V battery and connector (or 9V d.c. supply), printed circuit board.

even no reception, might be that you have connected either L1 or L2 into the circuit with the wrong phasing. To set up the radio for optimum performance you need to experiment with the positions of L1 and L2 on the ferrite rod. Once you have found the best positions, fix them with tape or glue. C2 can then be adjusted to give the best level of regeneration. Start with the trimmer fully unscrewed and graduallly adjust it, noting both the strength and number of stations that can be received.

You should be able to tune over the medium wave band, including all the BBC medium wave transmitters and some local radio stations. In the evening you may be able to receive some foreign stations as well, sometimes broadcasting right over the top of your favourite programme!

Although I used a slider pot for the volume control, an ordinary rotary pot could just as well be used instead.

As usual, one possible printed circuit layout is given in Fig.15 but try to work out your own. Don't have tracks very close together and don't have unwanted pieces of wire attached to your circuit. Stray capacitances can be quite a nuisance. Have fun and good luck! PE

POINTS ARISING

Teacher Power (Nov 87)

Fig. 15 page 40 (PCB details). Ignore note about IC2 leg swapping. The PCB is correct but the leg labelling should read from left to right as "Out, In, Com".

TEACHER LETTER

POINT IN TIME

Dear Sir

I wish to comment on Tim Pike's *'Teacher Timer'* article in the September issue. Though the first and last sections are very suitable, I cannot agree with part of the middle section.

Firstly, Fig.6 will not behave as stated. The transistor turns on after the same delay as for Fig.5, but the current then increases slowly. The capacitor voltage cannot rise above about 5V unless the transistor's gain (h_{FE}) is greater than 500. An alternative method is to swap over the led and the 470 ohm resistor, increase the capacitor to 4700μF and decrease the charging resistor to 47k. This method uses the I/V characteristic of the led to give a genuine delay, assuming the use of a small signal NPN silicon transistor with the minimum characteristic of h_{FE} 50, I_c (max) 20mA, and V_{EBO} (max) 5V.

In Fig. 7 the Schmitt-trigger action is prevented by the current through the third transistor, which therefore increases gradually, while the capacitor voltage rises from 2.5V to 7V. True Schmitt action can be produced by placing the led across the collector and emitter of the second transistor, with suitable component value amendments.

If it is preferred to make the Schmitt trigger completely independent of the led drive, the third transistor can be retained, but taking its emitter direct to ground, and inserting a suitable resistor in series with the led in the collector path.

I look forward to the rest of the series which is likely to be very helpful.

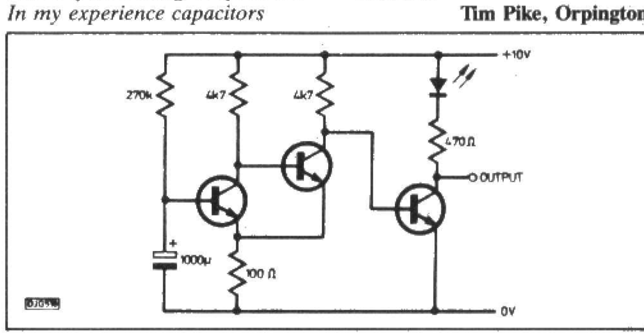
Bob Sharp, St. Austell.

In Fig.6 it is of course true that the threshold for the transistor remains at around 0.7V, but the effect of the emitter resistor is to provide some inherent negative feedback around the transistor. The transistor may begin to turn on after the same delay as in Fig.4, but as soon as the collector current is flowing, there will be a voltage drop across the emitter resistor, thus requiring a higher voltage on the base (and therefore across the capacitor) in order to keep the transistor biased on. I agree with Bob Sharp that a high gain transistor is required if the base is to reach 5V or more. I don't believe that I implied otherwise.

I agree that to swap the resistor and led gives a better solution in terms of delay achieved, but I would not agree to change the values of the biasing components. In my experience capacitors greater than 1000μF are relatively difficult to obtain and disproportionately expensive.

With Bob Sharp's point concerning Fig.7, I agree entirely, the third transistor should have been shown as a simple inverter following the standard two-transistor Schmitt circuit. It is important for GCSE students to keep ideas straightforward and therefore I would suggest that Fig.7 becomes the following circuit, which also allows for an output to be taken from the third collector.

Tim Pike, Orpington.



SOLAR CELLS

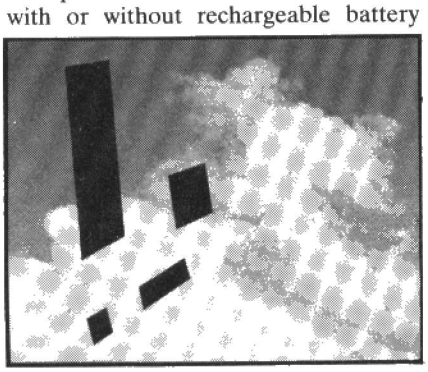
BY IAIN GARNER

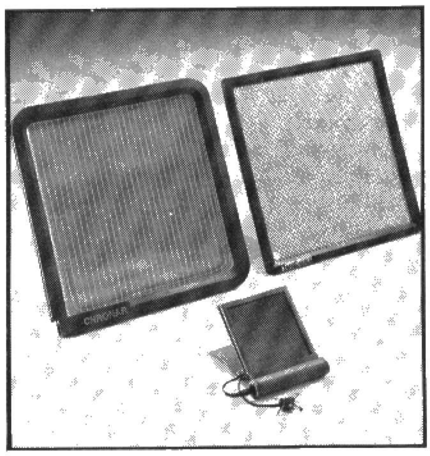
Amorphous silicon takes shape

The use of different types of photovoltaic cell to turn light into electricity is being constantly extended by OEMs. Here a manufacturer looks at future applications for amorphous silicon cells.

THE reliability, convenience and present cost of photovoltaic systems have brought solutions to power supply problems in telecommunications, navigation, pipeline protection and railway signalling. Smaller systems are being rapidly adopted in countries such as Spain, Norway and the USA, where remote and holiday homes have no other source of power to charge 12 volt battery supplies. Over many years solar modules have been used in sailing craft to power navigational instruments and are now being installed as original equipment. Similarly with the increasing sophistication of touring caravans and motorcaravans, in some cases extending to built–in air conditioners and microwave ovens, the need for a supplementary solar battery charger has been met by several European and British caravan manufacturers.

At the opposite end of the scale large quantities of small solar modules are being used in calculators, watches and earphone radios, in place of primary batteries. Here the bulk and cost of the power supply, combined with a low power requirement, means that a compact and inexpensive solar module can enhance the product. With the availability of mass produced, low cost amorphous silicon solar modules a sudden, large increase in applications to consumer products will continue these trends. The task for product designers, engineers and specifiers is to examine power requirements in co–operation with photovoltaic manufacturers. The possibility of replicating the success of solar calculators can be achieved by combining different sizes, shapes and colours of amorphous silicon solar modules, either with or without rechargeable battery





storage, in a wide range of small electrical products.

This article discusses some of the possibilities with reference to the size, cost and configuration of typical solar powered products. Emphasising the needs of original equipment manufacturers, design guidelines are established in anticipation of product development requirements.

MODULE SIZE AND POWER REQUIREMENTS

The major advantage of amorphous silicon solar modules is the technique used for interconnection of individual solar cells to produce a useful voltage and current. The p–i–n structure cells are fabricated by deposition onto an electrically conductive, tin–oxide coated glass sheet which is subsequently coated with a metallic back contact. The final module voltage is achieved by a set of stepped laser–scribed divisions which allow rear to front series connections between adjacent cells. Monolithic interconnection in this manner allows a wide variety of configurations without the need for the laborious soldering required with conventional discrete solar cells.

Individual solar cell output is approximately 0.8 volts (open circuit), corresponding to 0.55 volts on load for a cell width of 1 centimetre. The on–load current under bright sunlight is up to 10 mA per centimetre of cell length giving typical module efficiencies in the range of 4–4.5 per cent. Using these basic parameters, minimum module area can be established for a range of power requirements. Table 1 takes examples of products currently available from Chronar and other photovoltaic product manufacturers.

MODULE SIZE ANALYSIS

In module sizes up to 100 cm^2, the competitive advantage of amorphous silicon versus conventional cell materials is entirely dependent on the individual product. Crystalline silicon cells exhibit a greater power density typically 11–13% which, although at a greater cost (perhaps 20–25% more), may be important to a compact, portable product. Several examples of this have recently appeared in the market place notably solar ventilator fans, solar radios, solar key ring torches and a solar powered electric massage device. The problem facing a designer is to make the trade off between solar cell costs and conventional components such as batteries, motor or electronic controls. In many cases amorphous silicon would be cheaper, but would also demand the use of a slightly more highly specified component to keep module area within

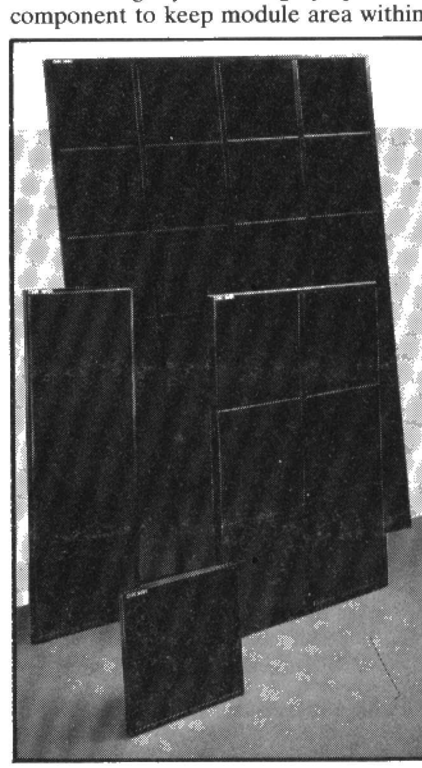


Table 1: Photovoltaic Module Specifications

Size	Area	Load Volts	Load Amps	Application
10 x 50mm	5 cm^2	2.5V	10mA	Credit card calculator
20 x 100 mm	20 cm^2	5.0V	20mA	Desk top calculator
50 x 130 mm	65 cm^2	6.0V	50mA	Solar torch (4W bulb with 3 @ AA NiCd rechargable batteries)
100 x 100mm	100 cm^2	5.5V	100mA	Battery charger (2 @ AA NiCd rechargeable batteries)
150 x 150mm	225 cm^2	7.5V	150mA	Garden light (0.5W bulb with 1.2 Ah 6V sealed battery)
100 x 300mm	300 cm^2	15.0V	100mA	12 Volt trickle charger for battery up to 30 Ah capacity
300 x 300mm	900 cm^2	15.0V	300mA	12 Volt trickle charger for battery up to 90 Ah capacity
300 x 900mm	2700 cm^2	15.0V	750mA	Garden light (16W bulb with 2 Ah 12V NiCd battery pack)

satisfactory dimensions. Of course the response should be to design a better product, but in many cases the use of solar power is seen, particularly by foreign manufacturers, as giving an edge to an otherwise marginal 'gimmick' product.

Above 1000cm^2 amorphous silicon modules are less likely to form an integral part of the product and can compete closely with conventional modules up to power outputs of 20 watts per installation. This category includes most recreational and leisure applications of solar power. However, special requirements for rugged modules in yachting or flexible modules for rough usage at present exclude amorphous silicon. For such special requirements additional lamination in glass is available for environmental protection but is not presently adaptable to military specifications.

Paradoxically, at extremely large scales of power system (over 100kW) amorphous silicon is the market leader, having the potential to compete directly with conventional generating plant in a grid connected system. This is largely due to the high costs of peak generating plant which may be run for short periods to meet high electricity demand, such as for air conditioning. Chronar has built and sold the first such plant, 100kW in size, to a utility company in the United States (Kiss [1]).

CHARACTERISTICS OF AMORPHOUS SILICON SOLAR MODULES

The physical and electrical differences between amorphous thin–film and crystalline silicon photovoltaic modules arise directly from their fundamentally different methods of fabrication. The following comparison in Table 2 deals strictly with mass produced cells and panels currently available following a previously published analysis by Hart [2].

While increased active area may be required to produce a given current, since monolithic series connections are more compact, amorphous silicon can compete directly with conventional materials. Where indoor usage is envisaged, or where high temperatures may be involved, the performance of amorphous silicon may be significantly better. In larger systems requiring in the region of 3.0A at 12V nominal, the additional area related costs for amorphous silicon modules may also be offset by the reduced high temperature performance of crystalline modules. Specifically, it is questionable whether closely packed cells can perform adequately in high temperatures, at least for battery charging applications. Packing density problems do not affect amorphous silicon modules due to the very small amounts of active material present.

PHYSICAL CHARACTERISTICS

A wide variety of substrates can be used for deposition of amorphous silicon. Several commercial products are now available using glass but it is equally practicable to use stainless steel or even certain plastics. The problem in all cases is to keep costs sufficiently low to maintain viability in the product.

The lowest cost material is glass, which is used widely for all sizes of modules. Above 900cm^2 the best policy is to adopt a second layer of glass in a laminated form for strength and environmental protection. Encapsulation is less critical in products primarily designed for interior use and typically a painted finish only is required to prevent damage to the back contacts during assembly. Various forms of vinyl encapsulation can also be used to provide easily adaptable sizes and shapes of module, suitable for exterior use.

Glass thickness is normally 3mm for the superstrate, with 1mm for a back cover on large area, laminated modules. However in small area modules up to 20cm^2 it is more practical to use a single layer of 1mm glass for ease of cutting. In products such as a battery charger or solar torch, the additional strength of 3mm glass is probably of greater benefit than the reduced weight. Some manufacturers have adopted various textured plastic covers to protect the glass surface on a thin module. However, this tends to reduce energy conversion efficiency in all but bright sunlight and is an additional major cost.

AMORPHOUS SILICON MODULE COSTS

While the whole photovoltaic industry is dependent upon volume, prices for specific applications cannot be anything more than guidelines. For typical systems a price of £4.00 being the module cost. This relates only to large systems serving professional applications, where the largest possible module units are employed, typically 40–50 watts each. Since most such applications are procured through competitive bidding, price and market share are often traded. Rarely, if ever will any company make a profit unless they supply the entire system, since engineering time is rarely costed–in.

Table 2: Comparison of Amorphous and Crystalline Solar Modules

Characteristic	Amorphous Silicon	Crystalline Silicon	Comment
Efficiency	4-5%	9-13%	Amorphous anticipated at 5-5.5 over 2700 cm^2 end 1987; target 10-11% by 1990
Stability	10% loss over 10-15 years	10% loss over 20 years	Amorphous instability now largely solved.
Spectral Response	70-80% at 440-650nm	75-85% at 550-700nm	Amorphous better under fluorescent light
I-V Curve	Fill factor low (50-60%)	Fill factor high (80%)	Low fill factor gives light level dependent output
	Low losses with temperature rise	High losses with temperature rise	Temperature can seriously reduce output of crystalline modules
Cell Interconnects	Monolithic	Discrete	Amorphous costs unrelated to area.

In applications requiring module sizes up to 20 watts prices reflect more closely the actual costs. There are more opportunities to design systems which can become standard products and prices of up to £13.00 per watt for the module alone are common for crystalline silicon. Amorphous modules would typically cost in the region of £10 per watt in the size range from 3 to 20 watts. Below 5 watts there is no competition; amorphous modules are now being sold at retail prices of £13 per watt.

Below 1 watt, or when module sizes are below 300 cm^2, the quantity for a given application will influence the selling price directly. In solar calculators retail prices from £50–100 per watt are common for a module of 5 cm^2. In battery chargers for two NiCd batteries the module components are sold at a retail price equivalent to £60 per watt and £45 per watt in a solar powered garden light.

In the above categories many individual products can be identified which would benefit from having no wiring, avoiding the necessity of replacing batteries, and operating whenever the sun shines without additional cost. Many examples have appeared in the last few years, but several are worthy of examination in more detail.

AUTOMOTIVE APPLICATIONS

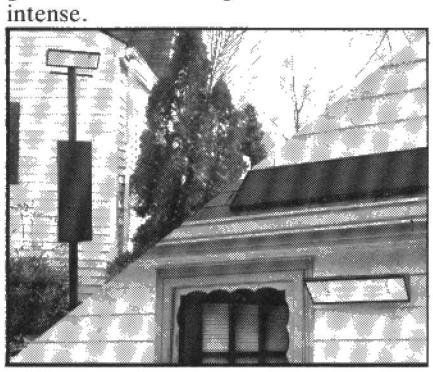
In the accessory "aftermarket" several suppliers are beginning trials with simple solar battery trickle chargers with the obvious intention that manufacturers should eventually include the idea as standard equipment. The need is due to pressure from two directions. First more electronic equipment is increasing "key-off" loads in modern cars, which when parked for several days can bring the vehicle battery down to a low state of charge. Second, batteries must become lighter to save fuel while retaining strength through the addition of calcium or antimony, unfortunately promoting battery self-discharge.

The addition of a solar panel in the vehicle roof or parcel shelf can alleviate these problems and add value to the product. For example, it may be possible to drive a ventilating fan during hot weather while the car is parked.

POTENTIAL APPLICATIONS

Although the number of potential applications of photovoltaic power is unlimited, and the list of existing applications growing rapidly, most photovoltaic consumer products can be grouped into one of three categories, relating to electrical storage (Garner, [3]).

Direct Solar Power products cannot store power, and so run only when light is available. Into this category fall solar powered calculators, digital thermometers and various kinds of fan. Of these, solar-powered fans are perhaps the most obviously appealing, as the need for ventilation is generally greatest when sunlight is at its most intense.



The second category consists of solar-powered devices which use a capacitor as the means of electrical storage, generally having an average power consumption of up to 1 milliwatt continuous, such as solar-powered clocks, smoke detectors, and micro-computer and calculator memories.

The third category combines a photovoltaic module with a battery. During daylight hours, solar cells operate both as a direct power supply and to charge small batteries, which then provide the load during night-time and extended periods of low light. In the consumer sphere, the most appropriate applications are for devices requiring a load greater than 1 milliwatt continuous, where extended night-time use is likely. Examples of such products include solar powered radios, televisions and lights.

DOMESTIC APPLICATIONS

This is potentially the largest market segment, but is dependent upon providing the right benefits to enhance a product. Garden lights without wiring, switching on automatically after sunset are a good example which can be extended into other areas of the home where power may be inaccessible. Other examples such as a solar powered air freshener may require careful design to optimise motor power, solar module size and cost.

The solar powered electronic scale very nearly duplicates the concept of calculators, while replacing batteries in hearing aids or clocks and watches can certainly provide improved convenience if not direct economic benefits.

There seems little doubt that the trend towards expansion in the number of battery powered products and the popularisation of rechargeable cells will continue. This trend can employ many of the advantages of amorphous silicon solar modules to provide a steady maintainance charge for nickel-cadmium or lead-acid batteries.

CONCLUSIONS

Photovoltaics, after a long gestation period, are here to stay and expansion into a broad range of applications is concomitant on the continuing reduction in prices. This is likely to depend largely on the successful large scale commercialisation of amorphous silicon solar modules and products. At present 20% of the world photovoltaic industry is dependent upon a single product: the solar calculator. If the industry is to survive and expand more innovative ideas must be found and developed. The potential is available in amorphous silicon to produce time-saving, convenience products at sufficiently low cost to generate an enormous solar powered consumer product market.

REFERENCES

1. Kiss, Z. Chronar Corp. Annual Report 1985, Princeton, NJ 08542, USA.
2. Hart, P.R. "Crystalline vs. Amorphous Silicon in Photovoltaic Applications", presented at 7th European Photovoltaic Solar Energy Conference, Seville, Spain, 27–31 October 1986.
3. Garner, I.F. "The Increasing Range of Photovoltaic Applications", presented at Power Europa '86, Weisbaden, West Germany, 3–5 June 1986.

For further information contact
Iain Garner, Chronar Ltd,
Unit 1, Waterton Industrial Estate,
Bridgend, Mid Glamorgan, CF31 3YN

BOOKMARK

The following books have recently been received:

Electronics — a Self-teaching Guide, 2nd Edition. Harry Kybett. Wiley Press. ISBN 0-47-00916-4. Teaches the basics of electricity and electronic components in a self-paced, self-instructional format. You do not need previous electronics experience to use and understand this learn-by-doing guide, though an appreciation of mathematical formulae would be desirable.

Computer Circuit Concepts. Saul Ritterman. McGraw-Hill. ISBN 0-07-052952-3. £12.95. Aims within over 400 pages to give a balanced approach to explaining what a computer does and how it does it. Nine chapters cover subjects from logic, gates, counters, mathematical operations, to memory and peripheral devices, concluding with a description of a complete computer from its architecture to programming techniques.

Chip Talk — Projects in Speech Synthesis. Dave Prochnow. Tab Books. ISBN 08306-2812-6. £12.00. A practical introduction to speech synthesis that shows you how to build your own low cost stand alone or computer interface synthesiser units. Interestingly, it also devotes ten pages to the SSI263A chip as used in the PE Micro-Chat (Aug 87).

Build Your Own Working Robot — The Second Generation. David L. Heiserman. Tab Books. ISNB 0-8306-2781-2. £10.35. Uses a step by step approach to break down the construction of a complex personal robot system into easy and logical sub-systems. Has more emphasis on electronics and control than on mechanics.

Op-Amps — Their Principles and Applications — 2nd Edition (1986). J. Brian Dance. Newnes. £4.95. Intended both for technicians and home constructors who require enough information about op-amps to use them in conventional circuits without in-depth study. Its practical approach is written in a simple non-mathematical style and is specifically aimed at the non-academic reader.

Practical Techniques of Electronic Circuit Design — 2nd Edition. Robert I. Bonebreak. Wiley. ISBN 0-471-85244-9. £42.65. Some familiarity and experience with electronic circuits are assumed. Although not a beginner's text, it is however, directed towards the straightforward design of electronic circuits by those who lack a strong background experience. It is more concerned with facts than formulae.

LEADING EDGE

Continued from page 8

America the wretched system has been referred to the National Bureau of Standards. In Brussels, two different departments of the Eurocracy are squabbling about it.

The new Philips system allows one copy of a recording to be made, but no more. This allays the record industry's worst fears about DAT, namely that once a digital copy of a compact disc or LP record has been made, any number of further digital copies can be made without any loss of quality. The Philips one-copy system is preferable to the CBS Copycode system because it does nothing to spoil the sound of the original recording.

Apparently oblivious to the political implications, Philips unveiled "one-copy" in London, on 29 April, when their lawyer Peter Plompen spoke at a seminar organised by the Copyright Unit of the European Economic Community. Ironically there was space in the time-table only because CBS had declined an invitation to talk about Copycode.

All DAT recorders are able to store extra digital information on tape along with the music. This can identify the recording by title or date. There is also room in the digital bit stream for "flags" which have no effect on the music, but can be sensed by any other piece of digital equipment.

The Philips idea is for DAT recorders to incorporate a simple circuit which adds an anti-copy flag to the bit stream whenever the recorder is used to copy music through its input sockets. The recorder also has a circuit which switches it off whenever it senses the presence of a flag. So when a DAT recorder copies music for the first time, the recording is perfect. But thereafter any attempt at copying the copy fails because the recorder switches itself off.

Already DAT recorders cannot dub in digital domain from CD because of deliberate mis-match of the sampling frequencies (44.1 kHz for CD and 48 kHz or 32 kHz for domestic DAT). The CD data stream has room for a copy-inhibit flag which does the same trick.

The Philips one-copy scheme overcomes the record industry's main objection to DAT, summed up succinctly by George Martin, ex-Beatles producer.

"The awesome thing about digital taping is that it isn't just taping, it's cloning" says Martin. "However many copies you make the product is just as good as you get in the studio".

Polygram, who back Copycode to the hilt, were angered by Plompen's lecture. Although the EEC seminar was open to anyone who was willing to pay £110 to attend and those who did were promised a written copy of Plompen's text, Philips said lamely the "English was not good enough to release". Now, several months later, Philips just pretends Plompen and his lecture never happened. PE

OUR REGULAR LOOK AT ASTRONOMY

SPACEWATCH

BY DR PATRICK MOORE OBE

The furthest object which we can detect from our solar system is outrunning us. Back here at home, Voyager 2 draws closer to Neptune.

Discoveries are made nowadays in rapid succession — and one has come from research carried out with the UK Schmidt telescope at the Siding Spring Observatory, New South Wales. Dr Cyril Hazard has located the most remote object so far known; it was recorded on a UKS plate. It is a quasar, with an estimated distance of around 13,000 million light-years. This means that it must be receding at well over 90 per cent of the velocity of light.

Hubble's Law states that "the further, the faster". If this Law remains valid, then we must eventually reach a distance at which an object will be receding at the full velocity of light, so that we will be unable to see it at all, and will have come to the boundary of the observable universe. It is generally thought that this critical distance must be between 15,000 and 20,000 million light-years, with a slight preference for the lower figure. It looks, therefore, as though the new quasar is well out toward the limit. Searches are continuing — probably the "distance record" will be broken again before long.

Discussions continue about the supernova in the Large Cloud of Magellan. It has now faded, but will probably be followed for many months yet, and perhaps even years, before it becomes too dim to be made out. It is certainly unusual; the blue giant star Sanduleak $-69^{P}202$ certainly seems to have been the progenitor, and since it had always been thought that supernovæ were caused by the deaths of *red* supergiants it looks as if some of our cherished theories will have to be revised.

The Sky This Month

Both the inner planets are on view during November. Venus has started to emerge into the evening sky, though it is still more than 90 per cent illuminated by the Sun and it is not likely that any surface markings will be seen on it — bearing in mind that a telescope will never show more than vague, cloudy features which are well nigh impossible to define. Mercury is at its best as a morning object, reaching its greatest western elongation from the Sun (19 degrees) on the 13th of the month. The phase increases from 25 per cent at the beginning of the month to 90 per cent at the end. There should be little difficulty in finding Mercury with the naked eye before dawn for the second and third weeks of November, provided that the skies are clear. The magnitude rises to −0.6, so that Mercury is actually brighter than any star visible from Britain apart from Sirius — though this is difficult to appreciate, because the planet is never seen against a dark background.

Mars is a morning object in Virgo, but is still a long way away, and not much brighter than the Pole Star. On November 12 it passes three degrees south of Spica. Jupiter, which was at opposition last month, is still visible for most of the night; it is in Pisces, and is a splendid sight in a telescope, though the famous Great Red Spot is obscure at the moment. Saturn has been more or less lost in the evening twilight, though it is worth noting that on November 20 Saturn and Venus are only two degrees apart.

There are two comets which may be worth looking for during November. One is Bradfield's Comet, 1987s, found by the famous Australian amateur; this is his thirteenth discovery, a record for our own century. It is expected to reach the 6th magnitude, in which case it will be on the fringe of naked-eye visibility, and there may be an appreciable tail. It will move in the general area of Serpens, Scutum and Aquila. The position on November 11, around the time of peak brightness, has been estimated as RA 18h 10m and declination −4°51'. The other comet, Rudenko's (1987u) is not expected to become brighter than magnitude 7 at best. In this case it should be fairly easy to locate, but it is passing through a region near the Virgo/Crater border which abounds in faint galaxies, and this may make identification difficult. Moreover, the comet travels rapidly south during November, and is not likely to be accessible after the end of the first week of the month.

Of course, November is the month of the Loenid meteors, which can provide the most spectacular of all "meteor storms" — as they did in 1833, 1866 and 1966. The maximum is on the night of the 17th/18th — but do not expect much this year. The Leonids will probably be sparse, and we are unlikely to have another major display from them until 1999. The Taurid shower is active from mid-October to the end of November, but it too is not likely to be striking. It reaches its maximum on the 3rd, but moonlight will interfere badly; the Moon is full on November 5 and new on the 21st.

There are no eclipses this month.

Orion is now starting to come into view in the late evening, reminding us that winter has arrived. Preceding it is the lovely cluster of the Pleiades; look at it with the naked eye on a clear night and see how many separate stars you can count (if you can make out a dozen you are doing very well indeed). The W of Cassiopeia is almost at the zenith, with Ursa Major, the Great Bear, at its lowest in the north — though of course it never sets over any part of the British Isles. We are losing part of the "Summer Triangle" well before midnight, though two of its members, Vega and Deneb, do not actually drop below the horizon. In the south there is the large, rather faint Cetus, the Whale; look for the famous long-period variable Mira, which can equal the Pole Star, but at minimum becomes so faint that even binoculars will not show it. It is due to reach maximum in January next year, but it may become visible with the naked eye during November. The Square of Pegasus is still conspicuous high in the south-west all through the evenings.

FIRST VOYAGER 2 VIEWS OF NEPTUNE

Neptune is the outermost of the known planets — at the present time, further away even than Pluto (though whether Pluto should be ranked as a true planet seems to be becoming more and more dubious). At its mean opposition distance, Neptune is more than 2,700 million miles from the Earth, and surface details are almost impossible to make out visually even with large telescopes, but it does look as though Neptune has more cloud activity than Uranus, and from Mauna Kea, at almost 14,000 feet above sea-level, Heidi Hammel has used the 88-inch reflector to take new pictures. The cloud features in the planet's southern hemisphere are well seen, and yield a rotation period of 17.9 hours. No bright clouds were seen in the northern hemisphere, though they had been recorded earlier, so it does seem as though there are marked variations. Neptune, of course, is a giant world 30,000 miles in diameter; it is slightly smaller but appreciably denser than Uranus, and does not share in Uranus' extraordinary axial inclination. Neptune takes over 164 years to complete one journey round the Sun.

Voyager 2 has already by-passed Jupiter, Saturn and Uranus, sending back close-range pictures of each. It is now en route to Neptune, and will make its pass in August 1989. The first pictures of the planet taken from Voyager have now been recieved. Naturally, they show no details; Neptune is nothing more than a tiny, blurred patch, and its larger satellite, Triton, is a dot of light — but we know that Voyager is in good health, and there is no reason to doubt that it will be successful in this, its final mission target.

At the moment we do not know a great deal about Neptune, and we do not know whether it has a ring; "ring arcs" have been suspected, but not with any certainty. We may expect a magnetic field and radiation zones, as with the other giant planets. Of special interest are the two Neptunian satellites; Triton, which is rather larger than our Moon and may have an appreciable atmosphere, and the tiny Nereid. Triton moves in a wrong-way or retrograde sense, and is the only large planetary satellite to do so (all the other retrograde satellites are asteroidal), while Nereid has direct motion, but an eccentric orbit resembling that of a comet.

What Voyager 2 will tell us remains to be seen, but great hopes are placed on it. If it should fail, then we may have to wait for many years before we learn much more about the outermost giant. PE

KLANG!

There are several locks on a building for which I have recently been made responsible, and the keys were specially cut for me.

The first time I needed to enter I began the unlocking procedure, starting with the burglar alarm entry timer. All went well until the final lock — the key wouldn't fit!

With the timer remorselessly counting down, I struggled to turn the key like a desperate James Bond trying to defuse a ticking atomic bomb. But unlike 007, I failed — the time expired and clanging alarm bells ripped the night air.

Try as I might, I could not get in to stop the racket. There was no option but to go for help from another keyholder; who lived all of two miles off. That's an awful long way when you haven't brought the car.

The resounding moral — don't just assume a system works — check it! **ED.**

Multizone detection keeps you safer and helps you save your sorrow as well as your property. Be alarmed before the goods have gone!

INTRUDER ALARM CONTROLLERS

PART TWO BY BILL KENT

Detectors deter delinquents

Part one of this article looked at some of the motivations for installing a burglar alarm, and described the principles and construction of simple control unit that activates a timed bell in the event of a detection circuit being broken. This month in part two, a more complex system is described that offers several levels of detection. (Fig.8).

It includes monitoring of two detection zones, an anti-tamper detector, a 24 hour detector (or 'granny-bashing!' alarm), latched intrusion indicators, timed bell duration, optional automatic alarm resetting, timed entry-exit control, and a latched strobe light control driver. It is principally for use with pressure pads, and magnetic contact switches, but could also be used with a variety of other detectors, such as infrared and ultrasonic devices. The use of the switches was described in detail in part one.

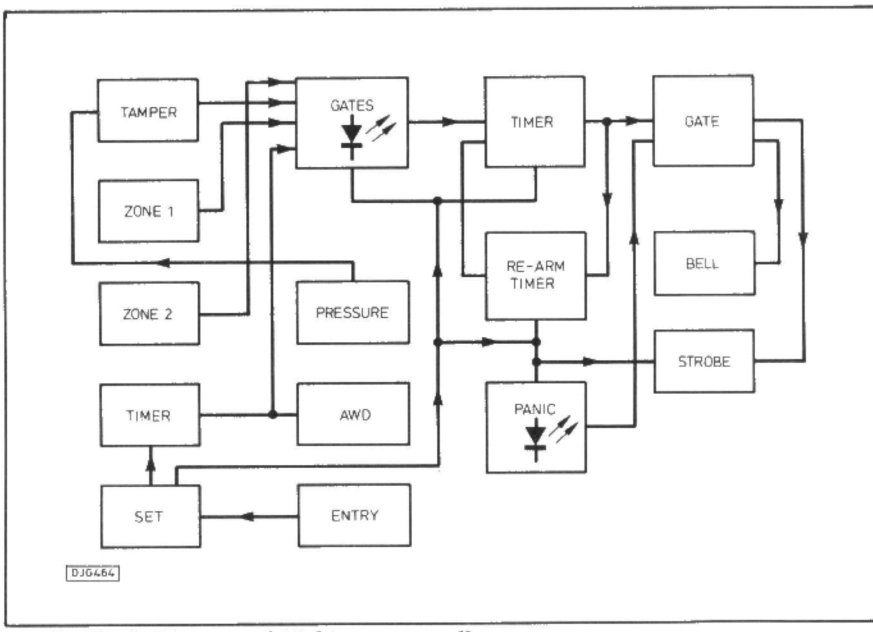


Fig. 8. *Block Diagram of Multizone controller*

MULTIZONE MONITORING

For any premises larger than just a room or two, it is a considerable advantage to know roughly which area has been subjected to unauthorised entry. For example, the front and the back of a house can be monitored separately, or the upstairs and downstairs treated as separate zones. On large premises there may be many zones, each of which are treated as independent regions. Not only does this help to locate the forced entry point, but also should any of the detectors fail, their location can more readily be determined. Each of the detection zones is monitored by a single master control unit that initiates the necessary action depending on the type of incident detected.

For an average sized domestic house the two zone system is probably adequate, the choice of zone separation being assessed by expediency. Detection within these zones will follow similar principles, that if the circuit status is disrupted, an alarm will be activated by the controller.

The simplest detection device is the magnetically activated contact switch, as discussed in part one. Under normal conditions this maintains continuity of an electrical loop. If the loop is broken, either by the opening of the switch, or the cutting of the connecting wires, a voltage change will take place, triggering the controller.

For the most part, in the system described here, the controller will see a zero voltage when the loop is closed. If the circuit opens, the controller then sees a positive voltage at its input. Looking at Fig.9, it will be seen that zones one and two have identical circuitry around IC1a and IC1b.

ZONE ONE

Taking zone one, IC1b is a latching gate, the input of which is supplied by a positive voltage via R4 and R5. The detector loop is connected between the junction of R4 and R5, a series of normally closed contact switches, and ground. When all the switches are closed, the resistor junction is held low, but if the circuit opens it will revert to its stable high state. Pin 4 of IC1b also goes high via R5. A clocking pulse is constantly being fed from the oscillator around IC3a and IC3b, to a common control input at IC1 pin 9. This signal triggers the gate to open, causing the output to take on the same state as its input. Here the output is fed back to the voltage input at pin 4, via diode D2. Because of the presence of R5, even if the loop circuit is reclosed, the input and the output will remain high until the chip is reset by a separate control signal. The latched output provides the voltage to turn on the led D12. This shows that at some time the circuit has been disrupted, however briefly.

Note that the LEDs for both zones and the tamper loop can be triggered even if the system is not set by S2, though the bell will remain silent.

TRIGGERING

At first sight it may appear that the output of IC1b should be the trigger source for the alarm activating circuit. This though, would not allow for the situation where the circuit was briefly opened, and then reclosed. Obviously it is undesirable for a burglar to trigger the bell circuit, disappear until the bell has stopped automatically, and then reappear knowing that his entry would not retrigger the bell. Consequently, the output of IC1b is only used to give a visual indication that the circuit has at some time been broken, in due course informing the rightful owner of the alarm status.

The bell triggering is carried out by taking the voltage at the junction of R4 and R5, feeding it via the OR gate IC2a, the inverter IC3f and then to IC4a. When the loop circuit is broken the resulting negative going pulse, generated by IC3f

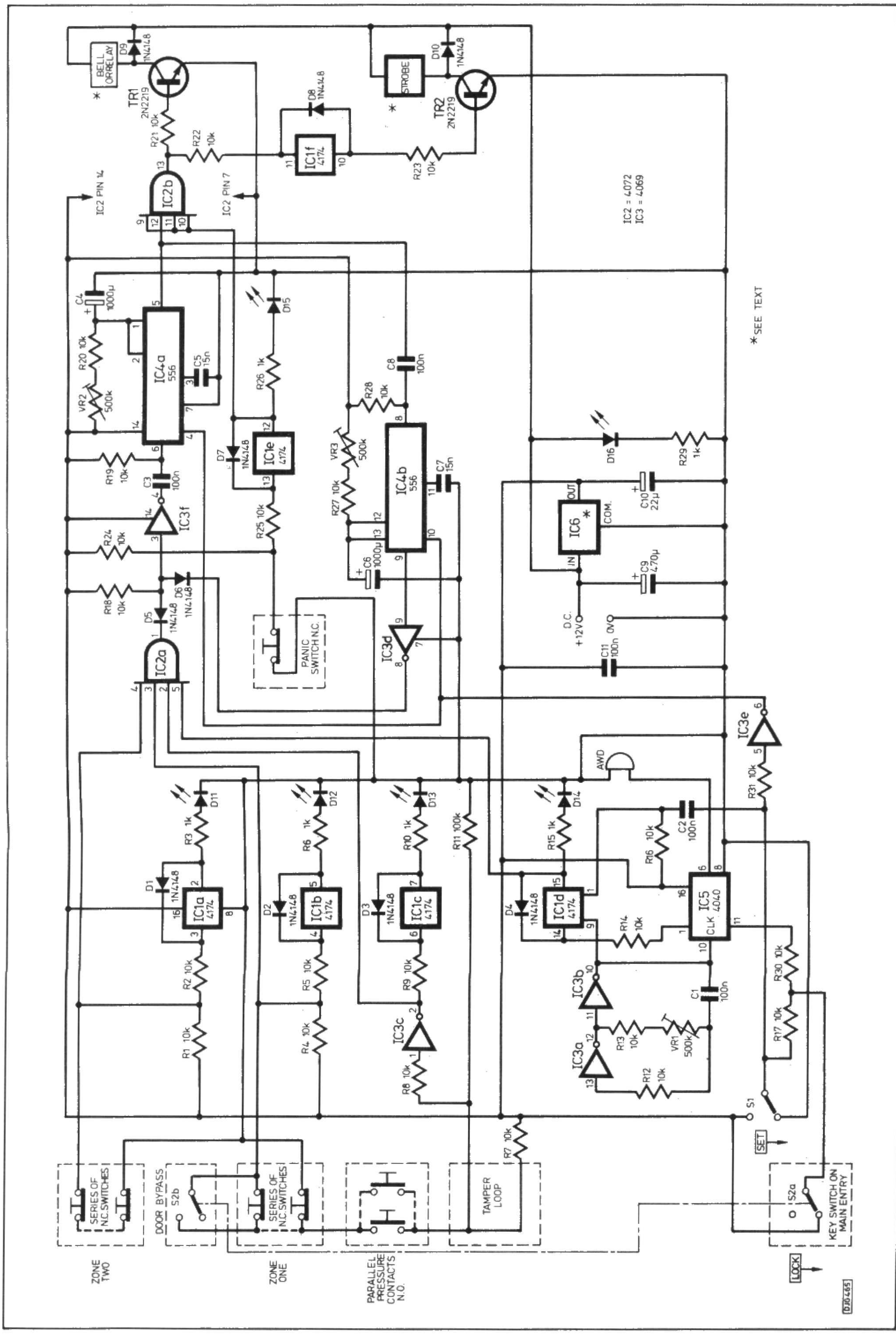


Fig. 9. *Circuit diagram of Multizone intruder alarm controller*

via the differentiator C3 and R19, triggers the monostable within IC4a. This operates in the same way as the 555 timer in last month's article, indeed IC4 is simply two 555s in one package. When triggered the output of IC4a goes high and remains so until C4 has charged up via VR2 and R20, whereupon the output will fall again. VR2 can set the duration between about 17 seconds and 15 minutes, within the restrictions discussed last month. The high output goes through the OR gate IC2b and turns on TR1, activating a bell or relay, with D9 quenching inductive transients. The operation and use of this stage is identical to that described in part one.

The output of IC2b simultaneously feeds another latch gate, IC1f, with R22 and D8 ensuring latching until reset. This turns on TR2, to which can be connected another relay, or a strobe light.

STROBE LIGHT

The use of a high power strobe on the outside of a building is of considerable value. If only a bell were to be relied on, once this had automatically been turned off by the timing circuit, there would be no external warning that the premises might have been entered illegally. This is a highly undesirable situation, for the intruder might still be around.

Additionally, the police may not have yet responded to the alarm call. This is not intended as a criticism, and the reasons could be any thing such as not being advised by neighbours that the alarm had sounded, or they had more emergencies to deal with than their numbers would allow. The presence of the strobe, which remains on until the system is deliberately reset, forewarns the owner of possible trouble, and is a visual indication to the police if they arrive after the bell has shut off.

TAMPER LOOP

Thieves can be cunning and try to beat any alarm system. System users have to make any attempts at bypassing the protections as difficult as expense and reason permits. One simple extra protection is to have an additional circuit loop alongside the entry loop, and within the same cable. This should be held at an opposite potential to the entry loop so that anyone interfering with the wires cannot readily determine which are which and so be in danger of triggering either circuit.

In practise, the use of a tamper loop may be debatable for some systems. If the wiring between units is inaccessible to intruders, the expense and inconvenience of extra wires may not be justified. The choice should depend on circumstances.

If required, the positively held tamper loop is taken via R7, around the complete system and back to the junction of R8 and R11. R7 is there to prevent anyone cutting through the wires from shorting out the full power supply. This of course would stop the system entirely. R11 is much larger than R7, so has little affect on the high voltage level seen at IC3a. If the lead is cut though, R11 pulls down the input of IC3c which, by inverting the polarity, puts a high level onto the gate IC1c. This responds in the same way as the latches of zones one and two.

COMPONENTS

MULTIZONE BURGLAR ALARM

RESISTORS

R1,R2,R4,R5,R7-R9 R12-R14,R16-R25, R27-R28,R30-R31	10k (24 off)
R3,R6,R10,R15,R26 R29	1k (6 off)
R11	100k

All resistors ¼W 5% carbon film

CAPACITORS

C1-C3,C8,C11	100n polyester (5 off)
C4,C6	1000µ 10V electrolytic (2 off)
C5,C7	15n polyester (2 off)
C9	470µ 25V electrolytic
C10	22µ 16V electrolytic

POTENTIOMETERS

VR1-VR3	500k skeleton (3 off)

SEMICONDUCTORS

D1-D10	1N4148 (10 off)
D11-D16	LED (6 off)
TR1,TR2	2N2219 (2 off)
IC1	4174
IC2	4072
IC3	4069
IC4	556
IC5	4040
IC6	7808 (see text)

MISCELLANEOUS

Pcb clips (4 off), PCB280A, 14-pin i.c. socket (3 off). 16-pin i.c. socket (2 off).

SECURITY PRODUCTS NEEDED: (SEE TEXT):
Bell, strobe light, magnetic contact switches, SP key operated switch, DPCO key operated switch, 4-core cable.

CONSTRUCTOR'S NOTE:
The PCB and a kit of parts is available from Phonosonics.

PANIC SWITCH

Although jokingly referred to as the 'granny bashing!' alarm, the panic switch has a deadly serious function. It is not uncommon for someone to talk their way into the house of an elderly or disabled person, and then to assault and rob them. To help guard against this situation it is recommended that a personal attack switch should be part of any system. Once activated this switch causes the bell to ring, but unlike the other trigger systems, the automatic timed bell cut off is bypassed. This means that the bell will go on ringing indefinitely until someone deliberately switches it off at the main control box. Some switches also have the additional protection of needing a special key to deactivate them. If granny, or anyone else feels in danger, pressing the attack switch should bring outside help.

The switch should be mounted in a convenient position, near the front door say, preferably a few feet back from it into the house. The switch should be a large press to open type that can be easily operated by a frail hand. I also feel that those likely to suffer from sudden illness would be well advised to also have a similar switch near floor level in a readily accessible place. Should anyone collapse and not have the strength to get up, if a low level switch is handy they might be able to attract help without waiting for the casual calling of a neighbour.

The circuit is around IC1e, and basically responds in the same way as zones one and two, being activated by the opening of the circuit. The circuit differs from the previous ones by taking the changing voltage level direct from the latched output of the gate. This then goes via the OR gate IC2b to turn on the bell and strobe light. It is totally unaffected by the action of the timer.

If more than one switch is needed, wire them in series in the same way as the contact switches. Anti-tamper wiring should be included here as well.

PRESSURE PADS

Should someone manage to bypass the window or door switches, additional protection can be offered by pressure pads underneath carpets. These contain normally open switches, closing if walked on. They should be wired between the postively held tamper loop, and the normally grounded contact switches. If the pad is pressed, the contact will activate the tamper loop trigger. Zonal monitoring display on the control panel has not been included for this circuit. However, a later section covers additional trigger circuits, and tamper loops could be zoned if needed.

TIMED PASSING

Putting the entry and exit switches under time control is a further hinderence to anyone who is illegally trying to get in or out. Keys to the control box and the main door trigger circuit need to be operated for authorised use. If the door lock is successfully bypassed, it will take time to bypass the box lock. By setting the delay between the door being opened and the bell being triggered to a reasonably short period, the risk of

successful dual lock picking can be reduced.

Prior to exit, the control box switch S1 is turned on. This sends a negative going pulse via C2 to the reset pin of IC1. If all the security switches are in the correct state, all LEDs D11 to D15 will go out. If a switch is in the wrong state, the light will be retriggered straight on again.

Before S1 is turned on, the counter IC5 is held at reset by the positive voltage via S1 and R30. Switching S1 on allows IC5 to start counting pulses from the oscillator around IC3a and IC3b. If S2a is not also switched on before the counter has reached half the maximum count, pin 1 of IC5 will go high, triggering the latch IC1d. The bell triggering line is taken from the latch output and will remain high until the system is reset again. If, however, S2a is correctly closed before the time out period, IC5 will be reset by the positive level via S2a. While the door is open, the door contact switch is bypassed by S2b.

RE-ENTRY

Before opening the door for entry, S2 is switched off first, enabling IC5 to start counting. If S1 is then switched off in time, IC5 will not reach its maximum, and so the system will not be triggered. If it is triggered, it will stay so until S1 is turned off.

The action of turning off S1 also resets the timer circuits IC4a and IC4b. The panic switch circuit though, will stay on with the bell ringing until S1 is briefly switched on and off again, resetting all of IC1.

The delay time can be set from anything between about 5 seconds and three minutes, and is controlled by the oscillator frequency. The oscillator is a standard twin inverting gate CMOS circuit, the frequency of which is set by the values of C1 and the total resistance of R13 and VR1.

Throughout the time that IC5 is counting, one of its early output stages is driving a low power active audible warning device mounted inside the box. This turns on each time the counter pin goes high, but becomes silent once the counter is reset. Some units use an internal AWD to indicate any triggered condition, but in this unit the external strobe and D11 and D15 are considered to be sufficient warning.

AUTOMATIC REPEAT

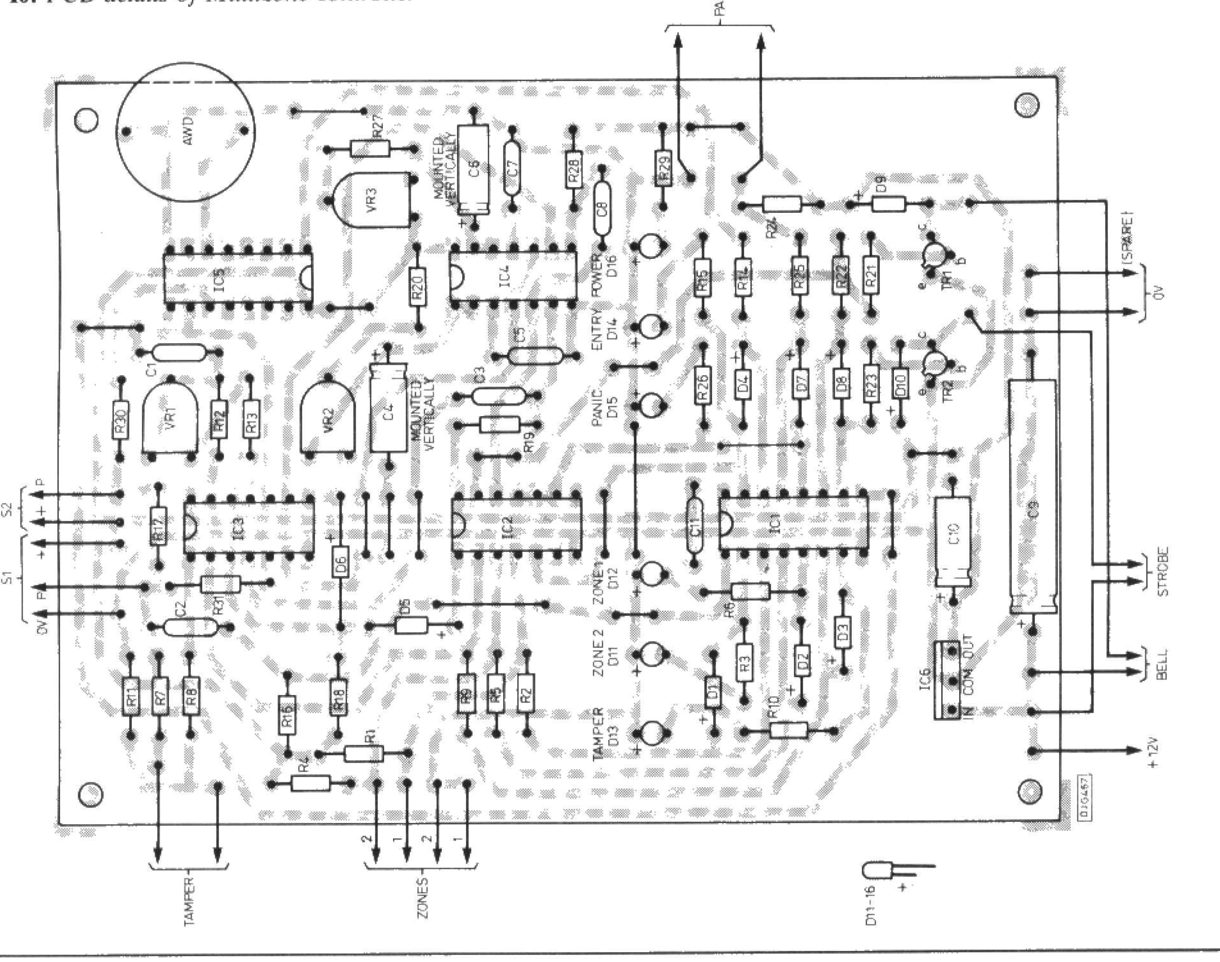
The desirability of an automatic re-arming circuit is open to discussion. On the one hand is the desire to give maximum protection against intruders. On the other hand is consideration for neighbours if the system should develop a switch or wiring fault causing triggering to occur. I can only say that the choice must be yours – the facility is included should you want it.

At the end of the bell on-time set by IC4a, the timer output pulse falls, and via C8 this triggers a second timer around IC4b. It is identical in operation to IC4a and has a similar timing range as set by VR3. At the end of its cycle, the negative going output level is inverted by IC3d and goes to D6. Between them D5, D6 and R18 form an AND gate. If any of the lines into IC2a are still high, the AND gate allows IC3f to retrigger IC4a. This cycle will go on indefinitely until either the system is reset, or the inputs of IC2a revert to their normal state. If they revert, the AND gate will not allow a pulse to be generated at C3. If the re-arm facility is not needed, omit C8.

POWER SUPPLY

Reading the British Standards recommendations for burglar alarms, there appears to be no standardisation on power supply voltages, though +12V seems to be common. However, the circuit here can be operated from any power supply between +5V and +12V. If the LED resistor values are increased, even +15V should be acceptable. Bells

Fig. 10. *PCB details of Multizone controller*



and strobes though appear to be more common for +12V supplies.

One intention of this unit is that it should be inexpensive, consequently, rather than recommend a fully stabilised mains PSU, with all its attendant mains safety factors, a normal 12 volt car battery charger is suggested as the PSU.

The output voltage should not be used directly to supply the circuit, but should be used with a 12 volt battery in parallel, of at least 3 amp hours capacity. A good heavy duty battery is essential for a reliable alarm system since it can supply power for prolonged periods during mains power failure or deliberate malicious switch off. Keeping the battery on constant trickle charge will ensure adequate supplies for the circuit as well as bells and strobes. Both the latter can be obtained as low current (typically 200mA) 12V units. For obvious security reasons the battery should be kept in the same box as the control board.

It is important to note though, that the charger should not be used without a battery in parallel with it. In the unloaded condition and without the storage capacitance function of the battery, the raw output of the charger can differ considerably from the rated value, and there will be a heavy ripple voltage. Conversely, the effect of smoothing capacitor C9 can result in an unregulated d.c. voltage of around 18V from some chargers.

The battery output is used to feed the bell and strobe direct, but the circuit uses a voltage stabiliser, IC6 to regulate the controller voltage at +8V. A +5V regulator such as a 7805 could be substituted if a 7808 is not available.

If the unit is to be used with ancillary detection equipment that puts out a trigger signal in excess of the stabilised PSU level, a voltage dropping attenuator should be included in the feed line.

Alternatively, the circuit could be driven by a more sophisticated mains and battery circuit, though at greater expense. In this case IC6 should be omitted.

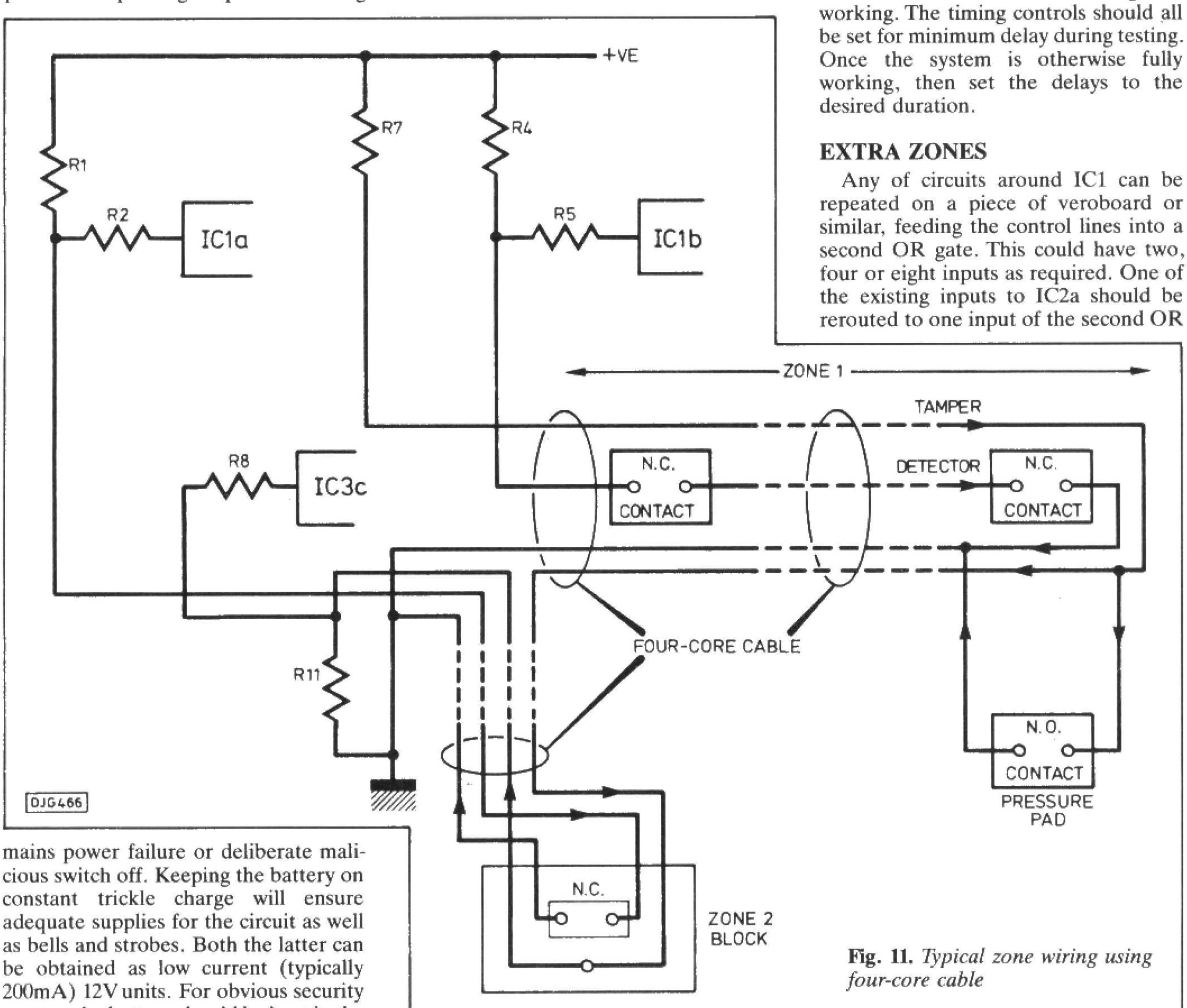


Fig. 11. *Typical zone wiring using four-core cable*

INSTALLATION

Since only one tamper loop circuit is included, its wiring must be connected so that all protected zones are served by the same wire. This means that all joins between the zones should keep the tamper wire lengths joined in series. If they are in parallel the trigger will not function. Fig.11 shows a typical arrangement. Basic switch types, routing and wiring are additionally covered in part one. Four core wire suitable for burglar alarms should be available from any supplier of security system parts. Note that the bell should also be included in the tamper wire.

Checking of the assembled control board (Fig.10) can be carried out systematically during the installation process. If any of the detector circuits are not used, the switch wiring should be replaced by a short link wire on the pcb.

Check out the response for each new switch or zone completed. During the early testing stages though, leave the bell cover off to avoid disturbing neighbours. The buzzing sound of the uncovered bell will be sufficient advice that things are working. The timing controls should all be set for minimum delay during testing. Once the system is otherwise fully working, then set the delays to the desired duration.

EXTRA ZONES

Any of circuits around IC1 can be repeated on a piece of veroboard or similar, feeding the control lines into a second OR gate. This could have two, four or eight inputs as required. One of the existing inputs to IC2a should be rerouted to one input of the second OR gate. The output of this gate then should come back into the now vacant input of IC2a. The gate is non-inverting so polarity changes will not occur.

RESPONSIBILITY

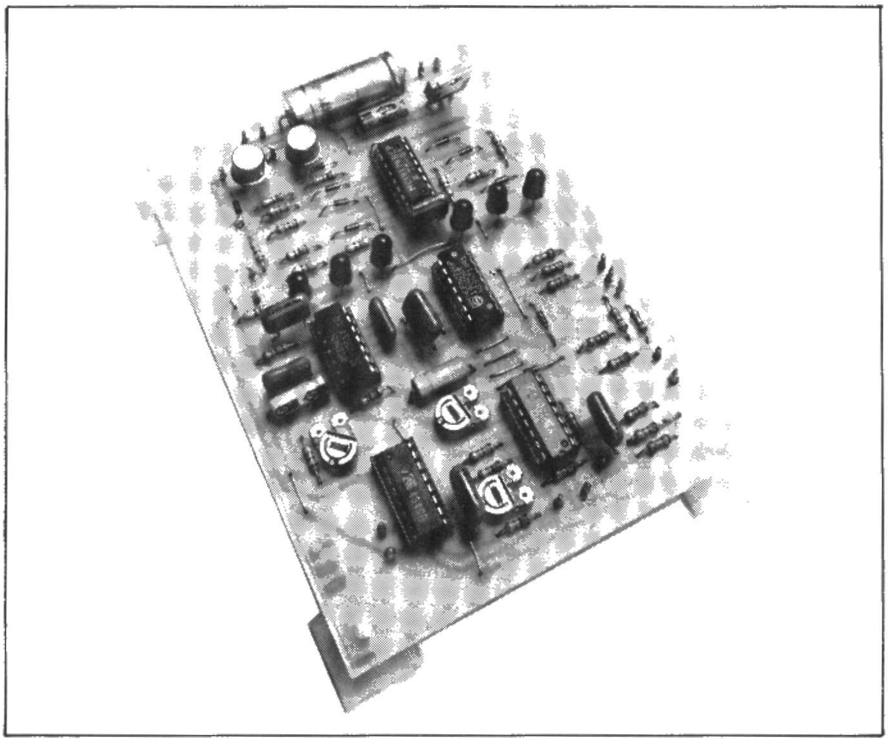
The installation of a burglar alarm involves the imposition of three levels of responsibility: on yourself, your neighbours, and the police.

Without the co-operation of your neighbours, the burglar alarm cannot assume its full potentional. Although the

sound of an alarm bell ringing is likely to scare off most intruders, you still need someone to advise the police that the system has been triggered. Someone should also hold entry keys in case of problems during your absence.

If you are on good terms with your neighbours there should be no embarrassment about asking them to act on your behalf. If you are part of a neighbourhood watch scheme, you probably have a co-ordinative arrangement anyway. Even if you are not in a scheme, at least one neighbour should be pleased to act – they may need a similar gesture from you in the future. So, pass a spare set of keys to a neighbour, and keep them informed about where you can be contacted in case of emergency.

Additionally, advise the police that you have installed an alarm, and who the keyholders are. This is part of their normal procedure and you need feel no reticence about informing them. The responsibility you place on them will be to their assistance, and they will be pleased to advise you on any security matter. They would sooner prevent crime than solve it, and an alarm system is a good crime deterrent. Certainly it will not prevent a persistent thief, but it will make most think twice before attacking your property.



The final responsibility is yours, firstly in carrying out the above, and, just as important, keeping your alarm system in good working order. Nothing brings them into greater disrepute than repeated false alarms. Try to ensure that the alarm never rings except in anger.

Surprisingly, the misinformed opinion still exists that an alarm advertises that you have something worth pinching. If you have, thieves may discover it anyway at any time. Deterrence is the better part of discretion, and in this case advertising your intention to keep thieves out is advantageous. So install an alarm, and use it. PE

READY-MADE P.C. BOARDS

Simplify your project assembly – use a ready-made printed circuit board. All are fully drilled and roller tinned. Just slot in the components as shown in the project texts, and solder them. **PCBs are the professional route to project perfection.**

MAIL ORDERING

Select the boards you want, and send your order to
PE PCB SERVICE, PRACTICAL ELECTRONICS, 193 UXBRIDGE ROAD, LONDON W12 9RA.

Prices include VAT and postage and packing. Add £2 per board for overseas airmail. Cheques should be crossed and made payable to **Intra Press.**

Quote the project name and PCB Code Number, and **print your name and address in Block Capitals.** Do not send any other correspondence with your order.

TELEPHONE ORDERS (OPEN 24 HOURS)

Use your Access card and phone your order to

0268 289923

clearly stating your name and address, Access number, and order details.

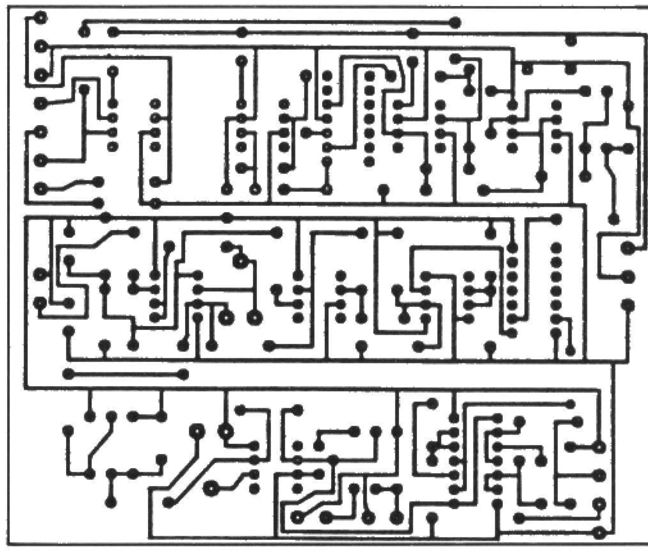
All orders receive priority attention, but allow 28 days for delivery in case a PCB is temporarily out of stock.

WE CAN ONLY SUPPLY THE PCBS LISTED HERE

CHECK LATEST ISSUE FOR PRICES BEFORE ORDERING

PHOTOCOPIES OF THE TEXTS MAY BE BOUGHT FROM THE EDITORIAL OFFICE AT £1.00 EACH PART (£1.50 OVERSEAS), P&P INCLUSIVE.
COMPONENTS ARE AVAILABLE FROM ADVERTISERS.

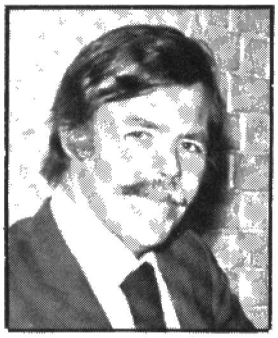
MAY 86		
NOTCHER EFFECTS – unusual harmonics.	107	£5.99
TTL LOGIC CHECKER – for 14 and 16 pin chips	108	£4.59
DF BEACON TIMER – accurate navigation aid.	109	£6.18
STE-BUS BACKPLANE – data and PSU routing socket board.	110	£14.97
JUN 86		
GUITAR TRACKER – transforms a guitar for sound synthesis.	111	£6.98
THERMOCOUPLE INTERFACE – transforms a DVM into a thermometer.	112	£3.90
PE HOBBY BUS – universal computer interface	113	£29.00
BBC LIGHT PEN – inhibiting, enhancing and visual feedback.	114	£3.90
JULY 86		
PASSIVE IR DETECTOR – burglar detection	115	£3.90
200MHZ COUNTER – professional specification	00D	£30.88
SEP 86		
FIBRE-OPTIC LINK – computer comms.	ODE	£10.14
PE HOBBY BUS – universal D-A and A-D unit.	120	£7.25
OCT 86		
DRUM SYNTHESISER – variable dynamic sound triggered effects.	121	£7.67
MAINS DELAY TIMER – selectable 15 to 120 mins. Set of 2 PCBs.	122	£7.92
MAINS DIMMER – touch control up to 400W.	123	£3.90
NOV 86		
REMOTE JOYSTICK – infrared computer controller. Set of 2 PCBs.	124	£10.86
BABY ALARM – through-the-mains transceiver.	125	£10.71
DEC 86		
VIDEO ENHANCER – manually adjustable video improvement.	126	£8.76



JAN 87		
VIDEO FADER – simple inexpensive video mixer	127	£4.50
VOICE SCRAMBLER – confidential trans.	128	£8.06
FEB 87		
HI STAB – good variable workshop PSU	132	£8.79
MAR 87		
4 CHANNEL ENHANCER – adapts stereo to 4 channels	135	£4.60
LIGHT PEN – uses fibre optics for high accuracy	136	£4.10
PHONE REPEATER – extra bell interface	137	£3.90
ULTRASONIC TAPE MEASURE – resolution to one centimetre	138	£9.50
APR 87		
VIGILANTE CAR ALARM – keeps cars alert to intruders	139	£5.90
INDUCTIVE LOOP TRANSCEIVER – remote control for models:		
...Transmitter	143	£3.90
... Receiver	144	£3.90
MAY 87		
BRIGHT FUZZ – Foot operated overdrive	145	£3.90
JUN 87		
AUDIO SIGNAL GENERATOR – uses frequency synthesising techniques	146	£10.20
JUL 87		
WORD GENERATOR – produces binary words of up to 16 bits	147	£13.42
SCOPE STORE oscilloscope add-on data storage	148	£11.94
AUG 87		
PSEUDO STEREO – mono to simulated stereo	149	£7.37
SEP 87		
SPEECH PROCESSOR – clarifies transmitted speech quality	150	£5.86
GCSE TIMER UNIT – versatile variable delay AWD and switching	151	£5.18
FUNGEN – triple waveform signal generator	152/153	£9.69
LIGHT CONTROLLER – delayed switching	154	£4.64
OCT 87		
TEACHER LOCKER – digital lock control	155	£7.50
POWER SUPPLY – stabilised ±15V	156	£7.50
GUITAR TO SYNTH – music interface	157A/B	£9.95
NOV 87		
DUAL POWER SUPPLY – GCSE	158	£6.20
MIDI EXPANDER – Music Interface	159	£5.04

THIS MONTH'S BOARDS

DEC 87		
RS 232C TO MIDI	160	£6.43
TEACHER RADIO – GCSE	161	£5.58



INDUSTRY NOTEBOOK

BRITAIN MUST CONTINUE TO CONTRIBUTE, TO BE HEALTHY

REPORT BY TOM IVALL

Overseas companies bring work into the UK, adding to our prosperity and strengthening our role in electronics worldwide. But the UK must not neglect its native industry for quicker rewards from elsewhere.

Good news for the end of the year: the indigenous UK electronics industry is doing reasonably well. By indigenous I mean companies founded in the UK, which are predominantly British-owned and whose fortunes are strongly linked to the economic health of this country. This category includes the big concerns like British Telecom, Ferranti, GEC, Plessey, Racal, STC, Thorn-EMI and a host of smaller firms too numerous to list here.

During 1986 I was reporting a whole series of poor financial results such as Racal's pre-tax profits plunging by over 30%, Ferranti's falling by 11% and — probably the nadir — the hitherto very successful company STC going into the red with a first-half loss of £8.7 million. But now these indigenous firms have largely pulled themselves out of their troubles.

STC, for example, has increased its pre-tax profit by as much as 46%, Ferranti by 22%, while Racal has pulled itself back by more than 11%. Even the temporarily loss-making Computer and Systems Engineering data communications company has reduced its previous year's loss of £14 million to £5 million (and is now predicting a profit).

It was sad, though, that Thorn-EMI had to resort to selling off its Ferguson business — a once-great name in radio and TV sets — to the French firm Thomson Grand Public. But there wasn't much hope of turning round the Ferguson losses of some £12 million in the face of the massive Far Eastern competition in electronic consumer goods.

You may well ask what is so important about these indigenous companies? Why follow their financial ups and downs with such concern? After all, it's often said that when the USA sneezes Britain catches a cold, and economically this is surely more significant than the affairs of a few home-grown electronics firms. And we do have subsidiaries of some excellent foreign electronics companies in the UK, bringing in advanced technology, providing employment and generally contributing to economic activity.

For example, to take three major competitor countries in this field, we have NEC Electronics from Japan, Siemens from West Germany and IBM United Kingdom from America. The last-mentioned alone has generated about 5000 jobs in UK manufacturing industry. Such foreign, often multi-national, companies also provide a useful spin-off in the form of business (and hence employment) for their multitude of suppliers in the UK.

This presence of foreign companies manufacturing in Britain is known as 'inward investment' and is often encouraged by the government through various incentives. It is genuine investment in that the foreign firms have to spend and risk money on their overseas ventures. But the point of an investment is to produce returns, and here's the rub as far as the host country is concerned. The benefits of larger markets (for Japanese companies the whole EEC), greater sales, higher volume production and hence economies of scale all go to the foreign firm. These benefits, and the 'repatriated' profits, help to boost the prosperity of some other country, not the UK.

But perhaps rather more negative is the fact that these chunks of the UK economy are controlled from outside Britain. A board of management in some foreign country can, at the stroke of a pen, simply close down a plant or shift it elsewhere, purely in the interests of that company. It does in fact happen, as we have seen recently during the world recession in semiconductors.

This kind of thing, although it may produce immediate job losses, does not shake the total economy too badly as long as it remains on a small scale. A good insurance against its effects is to maintain a strong indigenous electronics industry. Then, although we may be dependent on other countries for some products — as we are on the USA and Japan for standard integrated circuits — we are not dependent on them for everything. It's a matter of maintaining a workable balance.

There is no sure way to guarantee the existence and health of the indigenous electronics industry in Britain. The government can do a certain amount with financial grants, overseas trade assistance, placing of contracts etc. but in the end the outcome depends on the companies themselves. They have to stand up to world competition both in home and export markets, in order to keep their share of whatever business is going. That is why it is good news when we hear that the indigenous companies are doing better financially. While they are financially sound and producing adequate returns for their shareholders they are more likely to stay in the game.

What I have said could, of course, applies to any sector of British industry. But the situation is particularly crucial in electronics because this technology, and the production of goods and services resulting from it, is one of the industries of the future. Though not in its infancy like biotechnology, it obviously still has a long way to go. It is still an expanding part of the total world economy, and the current global rate of investment in research, development and new production techniques is an indication of what is to come. For the UK to drop out of the business through neglect, or be forced out by superior competition, would be extremely irresponsible.

However, I am not a nationalist, nor am I a techno-fetishist — a worshipper of technology for its own sake. Both of these aberrations have had unhappy effects on human life. There is now a much greater need for innovation and development in the social/personal sphere than in technology. The historian R.H. Tawney has written: "As long as men are men, a poor society cannot be too poor to find a right order of life, nor a rich society too rich to have need to seek it." We have to find a civilised balance between the material basis and the social consequences. Coming to terms with the realities of competition in today's world is just one aspect of good housekeeping. PE

INDEX

JANUARY 1987 TO DECEMBER 1987

VOLUME 23

Constructional Projects

Regular Features

Special Features

Autobutler by R Mishra. Unweaves a delightfully told predictive tale showing how technologically aided humanity might someday be free to enjoy living. **July**

Battery Update by R Cooper. A follow-up to the 1986 series of articles on batteries. **May**

Click Eliminators by the Prof. The design theory behind pulse blankers. **October**

Component Technology by G Nalty. Merits of high quality components for Hi-Fi. **August-September**

DC Motors by B Brooks. Their principles, characteristics and applications. **March-April**

Electrical Safety by R Stuart. Vital points relating to mains safety make essential reading **May**

Flight 68K – Review by R Penfold. Independent examination of a comprehensive commercial microprocessor development and teaching system. **July**

Frequency Synthesisers by the Prof. What they are and how they are used in numerous applications. **June**

Hi-Fi Design by G Nalty. Circuit ideas and considerations for true hi-fi enthusiasts. **January**

Lasers and Optic Fibres by B Fox. A look at the history and present day techniques of communications by light. **November**

Liquid Crystal Displays by R Penfold. Applications of LCD technology. **February**

Microwaves by A Armstrong. The use and nature of microwaves – two technology applications reports. **January-February**

Midi Interfacing by the Prof. Musical instrument control via dedicated data links is simpler than you might think. **September**

Oscillators by A Armstrong. A technical discussion about various types of oscillator, with circuits. **May**

Power Supplies – Low Drop Out by B J Frost. Designing battery powered PSUs for test and development use. **February**

Printing PE by J Becker. The Editor's discovery browse around look behind the scenes at the printing presses. **June**

Programmable Logic Devices An explanatory series of articles. **October – November**

Red Boxes – Review by R Stuart. Computer add-ons for various home control applications, particularly security. **February**

Robotics in Classrooms by L Hamburg. A tutor's experience of teaching analysis techniques through robot control. **November**

Semiconductors by A Armstrong. A series of articles demystifying the business of choosing and using semiconductors. **November-December**

Sensors – Part 1. by the Prof. Hall effect, gas, light and strain sensing devices **April**

Sensors – Part 2. by the Prof. Thermocouples, pH probes, and pyro sensors are looked at in detail. **May**

Signal Processing – Part 1 by the Prof. Analogue signal handling, with special regard to Dolby, companding, noise gates and delay lines. **July**

Signal Processing – Part 2 by the Prof. Digital sampling. **August**

Solar Cells by I Garner. Practical devices and techniques for harnessing solar energy in consumer applications. **December**

Stebus Specs by R Whitlock. Part Two. Read and Write timing details. Part Three, final details. **January-February**

Surface Acoustic Wave Devices by A Armstrong. Examines the technology and various applications of SAW devices. **March**

Switch Mode Power Supplies by R Penfold. Explains the design principles involved in SMPUs. **April**

Telephones by B Drake. A historical look at how telephone networks came about, and how they may develop **December**

TV Receivers by M Sanders. An inside look at the processing techniques used within The Box. **June**

Ultrasonics in Measurement by the Prof. Discussion of experimental considerations. **February**

Woodpecker Further information on Russian high power transmissions. **August**

30+30 Amplifier-Review by R Penfold. An independent critique substantiating performance claims. **February**

Summary Points 1987

AMSTRAD EPROM PROGRAMMER (Apr 87)
Fig 1. IC1 pin 12 links to IC1 pin 11. On IC2 CF should read FF, CX should read EX. On IC3 pin 26 is Vcc. FBXX-FAXX should read F8XX-FBXX. Point FX on IC2 pin 9 is not normally connected, but is a decoded port address for FO-FF hex which can be used in place of the EX address (IC2 pin 11) if this clashes with other equipment. Expansion port WR pin 36 should read pin 33.
Fig 2. A11, A12 A13, CSEL, PULSE are pins 17, 13, 12, 11, 10 respectively of Port C. ZIF socket +5V is pin 28, GND is pin 14.

CORRIDOR LIGHT CONTROL (Sept 87)
It is essential to ensure that correct mains wiring polarity is observed, and that the unit is preceded by a switch that can isolate it from the mains.

FIBRE-OPTIC LIGHT PEN (Mar 87)
Fig 2. TR1 and TR2 labels should be exchanged.

FIBRE-OPTIC LINK (Oct 86)
The opening line should read 'TR3 is the phototransistor, and it is given a small forward bias by R9'.

FUNGEN (Sept 87)
The correct component values are those on the circuit diagram Fig 3 page 36. In Fig 4 all transistor pins should read CBE when viewed from top, flat facing left, clockwise from top.

INFRARED TRANSCEIVERS (Jun 87)
Fig 3. R7 goes to IC2 pin 11.

MICRO-CHAT (Aug to Sept 87)
Fig 4 page 16 (PCB details). Orientation of IC2 and LP1 should be reversed. TR1 goes in holes above R3, pins reading CBE.

POLYWHATSIT (June 87)
Fig 2. IC18 pin 1 goes to 0V. IC18 pin 9 goes to pins 9 of IC10-IC12. The PCB is correct. There are minor apparent differences between the switch wiring in Fig 2 and Fig 5; Fig 5 is correct. These corrections do not affect the correct functioning of the unit.

PROMENADER (Dec 86 to Feb 87)
The capacitor across R9 on the PCB is C19 at 10μ 16V. C10 is 10μ 16V. R21 is 4k7. R26 is 10k.

SCOPE STORE (Jul 87)
Fig 3. Polarity of D3 and D4 should be reversed. C12 should go to junction of D1 and D2 (cut track from C12 to D1, then hardwire it to correct point). Parts list, C9 and C10 should be 100μF 16V electrolytic, and omitted C11 is 100p ceramic plate.

SWITCH MODE PSU (Apr 87)
Pages 28 and 29: diagrams for Figs 5 and 7 should be transposed. Pages 35 and 37: Figs 2 and 7 should be transposed.

TEACHER POWER (Nov 87)
Fig 15 page 40 (PCB details). Ignore note about IC2 leg swapping. The PCB is correct but the leg labelling should read from left to right as "Out, In, Com".

TELEPHONE BELL REPEATER (Mar 87)
Fig 3. Bridge rectifier BR1, top RHS pin should be a.c., bottom RHS pin should be negative. C2 LHS pin is positive.

VIDEO FADER (Jan 87)
Fig 5. The polarity of C2 should be reversed.

VIGILANTE CAR ALARM (Apr 87)
Gremlins crept in overnight on pages 24 and 25! Anybody who is puzzled about the wording continuity should send a stamped addressed envelope for a copy of the pages as they should have been.

ZX SPECTRUM PORT (Jun 87)
IC3a and IC3b symbols should be OR gate symbols.

30+30 AMPLIFIER (Mar 87)
Fig 1. 'Right -VE from C35' should read 'Right -VE from C36'. 'Left +VE from C36' should read 'Left +VE from C35'. R124 (middle LHS) should be R144. C32 and C132 go into spare holes by IC2 and IC102 respectively. R15 goes into spare holes below C5, C8 then goes where R15 is marked.